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DESIGN OF A TEST KIT FOR DETERMINING POLYELECTROLYTE DOSAGES PR--ETC(U)
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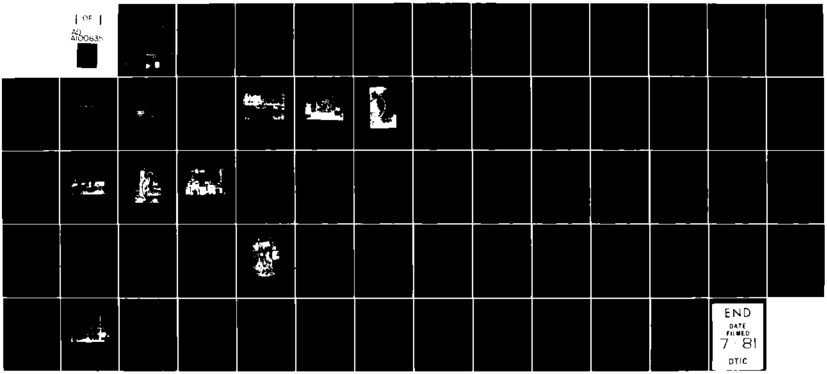

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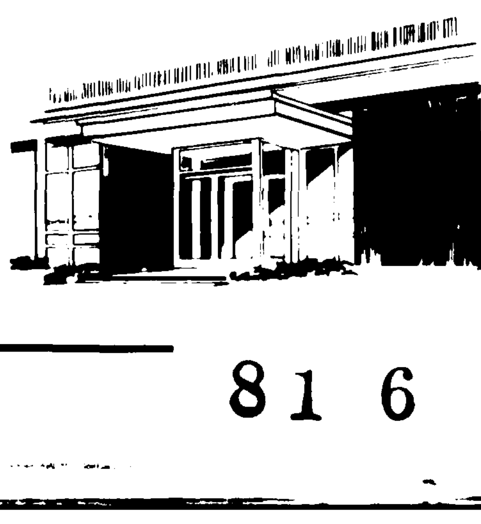

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DESIGN OF A TEST KIT FOR DETERMINING
POLYELECTROLYTE DOSAGES PRIOR TO
DIRECT FILTRATION

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SUMMARY

The purpose of this study was to develop a test kit which could be used for on-site prediction of the polymer dosage required for direct filtration of water sources such as streams and rivers. Criteria established for the test kit are that it be simple, rugged, fast, repeatable, and compact. An "ideal" test kit would be one that could predict effluent turbidity, run length, and potential failures, besides optimum polymer dosage.

The first test kits tried represented very simple and quick methods: pouring dosed influent through granular or paper media filters. Side-by-side tests using these test kits and the Army pilot multi-media filter showed that these techniques would not be suitable.

A small scale multi-media test kit called an interface monitoring test kit, was successfully developed that approached the "ideal" test kit requirements. This test kit, which monitors effluent turbidity through coal medium, as well as through all the media under steady state conditions, appears to be the most promising test kit method because:

a. It uses the identical filtration mechanisms as the full-scale filter.

b. It sensitively and accurately predicts optimum polymer dosage and closely approximates the effluent turbidity of the full scale filter.

c. It is a renewable test kit, i.e., backwashing allows it to be repeatedly reused requiring only small quantities of polymer for each test.

d. It can be constructed and repaired, if necessary, from off-the-shelf components.

The process design for the test kit is included in this report. It is recommended that a prototype test kit be constructed and tested on a variety of natural water courses. It is thought that the two operational parameters which the test kit could not predict, i.e., run length and failure mode, can be established on the basis of correlations developed during this further testing.

CONTENTS

FIGURES

FIGURES (continued)

TABLES

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the Project Officer, Mr. Maurice Pressman, as well as the following members of the Rexnord Environmental Research Center who provided valuable input into the experimental study: Anthony Geinopolos, Richard Wullschleger, Steven Galewski, Kathryn Huibregtse, Nicholas Kobriger, Donald Carr and Joseph Kuderski. We also wish to acknowledge La Donna Leazer for preparing the manuscript.

SECTION 1

INTRODUCTION

BACKGROUND

The U.S. Army Mobility and Equipment Research and Development Command (MERADCOM) is developing mobile water purification equipment to provide potable water for troop support. Testing is underway on a 38 l/min (600 gal./hr) unit which includes a multimedia filter, cartridge filter, and reverse osmosis module. The operating parameters for the pressure-type multimedia filter have been established by the U.S. Army and are presented in Table 1.

Polymer, used as a filtration aid, is added just upstream of the filter in such a way that, through turbulence, it becomes thoroughly mixed with the influent water prior to contacting the filter media. Prior experience with the use of polymers as filtration aids has indicated the need to establish proper polymer dosages for each application. Both underdosing and overdosing can cause problems. At this time there is no quick and efficient method to determine in advance the necessary polyelectrolyte dosage for variable water supplies. Development of a suitable method to establish polymer dose for the filter in the field is the subject of this project.

OBJECTIVES

The objectives of this study were twofold:

1. To identify a bench scale procedure which can be correlated to the full-scale multimedia filter used on the Army water purification system.

2. To design a small scale testing kit which will identify "optimum" polyelectrolyte dosages for direct filtration of water sources.

The criteria established for selection of suitable candidate bench scale procedures which could be used as polymer dosage test kits were as follows:

1. Rugged - The unit must be resistant to breakage and be capable of withstanding significant shock loads without having its usefulness impaired. In addition, the system must be capable of withstanding extremes of heat and cold.

TABLE 1. OPERATING PARAMETERS FOR U.S. ARMY MULTI-MEDIA FILTER.

Dimensions	in.	cm
Filter diameter	30	76
Filter height	58	147
Freeboard	13.8	35
Media (top to bottom)	lb	kg
Plastic chips	55	25
Anthracite	350	159
Silica sand	225	102
Garnet sand	175	79
Medium gravel	250	114
Flow rate	gal./min	l/sec
	30	1.9
Loading rate	gal./min-ft^2	l/sec-m^2
	6.11	4.15
Backwash sequence*		
Period, min	Flow rate	
	gal./min-ft^2	l/sec-m^2
2	14.3	9.7
7	24.4	16.6
2	14.3	9.7
2	Settle media	
3	14.3 downflow rinse	9.7
Polymer	10,000 mg/l stock Cat Floc T-1 solution	
Polymer dose	0-5 mg/l	

*Filter is backwashed when the pressure increases by 5 lb/in^2(0.35 kg/cm^2) or after 8 hours. whichever comes first; no air scour.

2. Simple to operate - The approach must be straightforward and the test simple. Standard pieces are required which are simple to use and replace. Subjective judgment of results must be eliminated or minimized.

3. Repeatable - The tests performed must be repeatable; the system must be able to be cleaned thoroughly and easily between each use, and the analytical test results must be reproducible.

4. Fast - The system should be capable of providing dosage results quickly. Therefore, dosing of several samples at one time may be required.

5. Compact - The unit should be small, able to be carried easily and shipped in a small space.

Experimental Filter

To perform the correlation tests, the Army supplied a 20 in. (50 cm) diameter pilot multi-media filter, along with a chemical feed pump, a 500 gal. (1893 liter) rubber stave tank to store filter effluent for backwash, and 10 gal. (38 liter) of polymer. To duplicate the operation of the full-scale 30 in. (75 cm) diameter Army filter, the filtration and backwash rates used in the pilot filter were scaled down from those presented in Table 1 to represent the same flow per unit area values.

PREDICTABILITY FACTORS

Before searching for bench scale procedures to establish proper polymer dosages for filtration, it was necessary to define those parameters of filter performance which need to be predicted and used to establish "optimum" operating conditions for the filter.

Effluent Turbidity

The most obvious factor in filter performance is the quality of the effluent produced by the filter. The particulate which penetrates the filter must be removed by subsequent cartridge filtration to protect downstream reverse osmosis modules. The unit of measure of penetration is the mass of particulate passing the filter per unit volume of filtrate.

The Army has not identified maximum allowable penetration for this project, therefore, the criterion that will be used is that it be as low as possible.

There is another definition of penetration which does not have a useful application in this study, i.e., penetration as the percent of the influent particulate passing the filter. A criterion based on this definition of penetration would result in a limit for effluent particulate which was a function of influent particulate concentration. The goal of filtration in this study is to provide the lowest achievable effluent concentration, regardless of the influent concentration.

The measure of effluent concentration during this study was by turbidimeter which is a light dispersing method for sensing the presence of particles.

Run Length

Run length is defined as the period of time from startup until shutdown of the filter. An eight hour run time is desired by the Army. Besides equipment malfunction, premature termination of filter operation may result from two types of process failures:

1. Blinding - Buildup of differential pressure because of flow restriction caused by the accumulation of particulate material within the filter. The Army filter system is designed around a maximum operating differential pressure of 5 lb/in^2 (0.35 kg/cm^2).

2. Breakthrough - Penetration of materials through the filter which result in an unacceptable rise in effluent turbidity. Since no maximum allowable penetration has been established, breakthrough in this project will be defined as any significant rise in effluent turbidity from steady state operation.

Premature failure results in a decrease in the net filtration rate. This can be expressed using the following relationship:

$$R_F = \frac{V_F - V_B}{T_F + T_B}$$

Where:
R_F = Net filtration rate, gal./min
V_F = Filtrate volume, gal.
V_B = Backwash volume, gal.
T_F = Filtration time
T_B = Backwash time

Examples: Contrast a four hour to an eight hour run length.

A. 8-hr run length

$$R_F = \frac{14,400 - 1330}{480+16} = 26.4 \text{ gal./min.}$$

Where:
V_F = 480 min x 30 gal/min = 14,000 gal.
V_B = 4.90 ft^2 [14.3 gal./min-ft^2 x 7 min + 24.4/ min-ft^2 x 7 min] = 1330 gal.

B. 4-hr run length

$$R_F = \frac{7,200 - 1330}{240 + 16} = 22.9 \text{ gal./min.}$$

Where: V_F = 240 min x 30 gal./min = 7,200 gal.

Cutting the run time in half decreases the net filtration rate by 13 percent. Further decreases in run length will cause more significant losses in net filtration rate. For example, cutting the run time by a factor of four to two hours results in a 37 percent reduction. A one hour filter run will be associated with a 76 percent reduction in net filtration rate. Thus, the criterion for run length is to have the longest run length possible up to 8 hours.

Monitoring of Failure Modes

Besides causing a reduction in net filtration rate, premature filter failure also carries with it the potential for significant contamination of downstream processes if the filter run is not terminated immediately following a breakthrough. Blinding does not hold a similar potential for disruption of downstream processes because the system has a differential pressure switch to sense overpressurization and initiate backwash.

"IDEAL" TEST KIT

Besides the four selection criteria for test kits stated under Objectives, a test kit was sought which could predict as much of the following information as possible:

1. Polymer dosage.
2. Effluent turbidity
3. Run length
4. Failure mode (blinding or breakthrough)

SECTION 2

ORIGINAL EXPERIMENTS

SELECTION OF TEST KITS

The first test kits considered were chosen on the basis that they met the selection criteria to the greatest extent possible, i.e., rugged, simple, fast, compact. They consisted of:

1. A mixed media filter constructed as a small diameter column using the identical media, i.e., coal, silica and garnet, as the pilot filter at half the full-scale media depths.

2. Stacked filter papers (Whatman Filters) in various combinations to attempt to simulate depth flocculation and filtration through a series of surface filtration steps.

3. Flocculation and sedimentation in a beaker.

The original versions of these test kits involved no moving parts other than a spoon-like stirrer. In the case of test kit no. 3, the stirrer was used for both rapid mixing and flocculation. In the case of the filtration test kits, no. 1 and 2, the stirrer was used only for rapid mixing; flocculation was intended to be accomplished within the filter itself similar to the way the pilot filter operates.

Preliminary testing on grab samples of water from local streams indicated that the first two methods deserved further evaluation. This preliminary work showed, however, that it was extremely difficult to achieve consistent results when attempting to flocculate with a hand-held stirrer and so further evaluation of test kit no. 3 was, at least for the time being, suspended.

TEST KIT CONSTRUCTION AND EVALUATION

The remaining two methods (test kits 1 and 2) were constructed as simple, open top plexiglass cylinders; five of each type were built so that five different polymer dosages could be tested simultaneously (Figures 1 and 2).

The operating procedure for the test kits was as follows:

1. A 1000 ml graduated beaker was filled with a sample of the influent water.

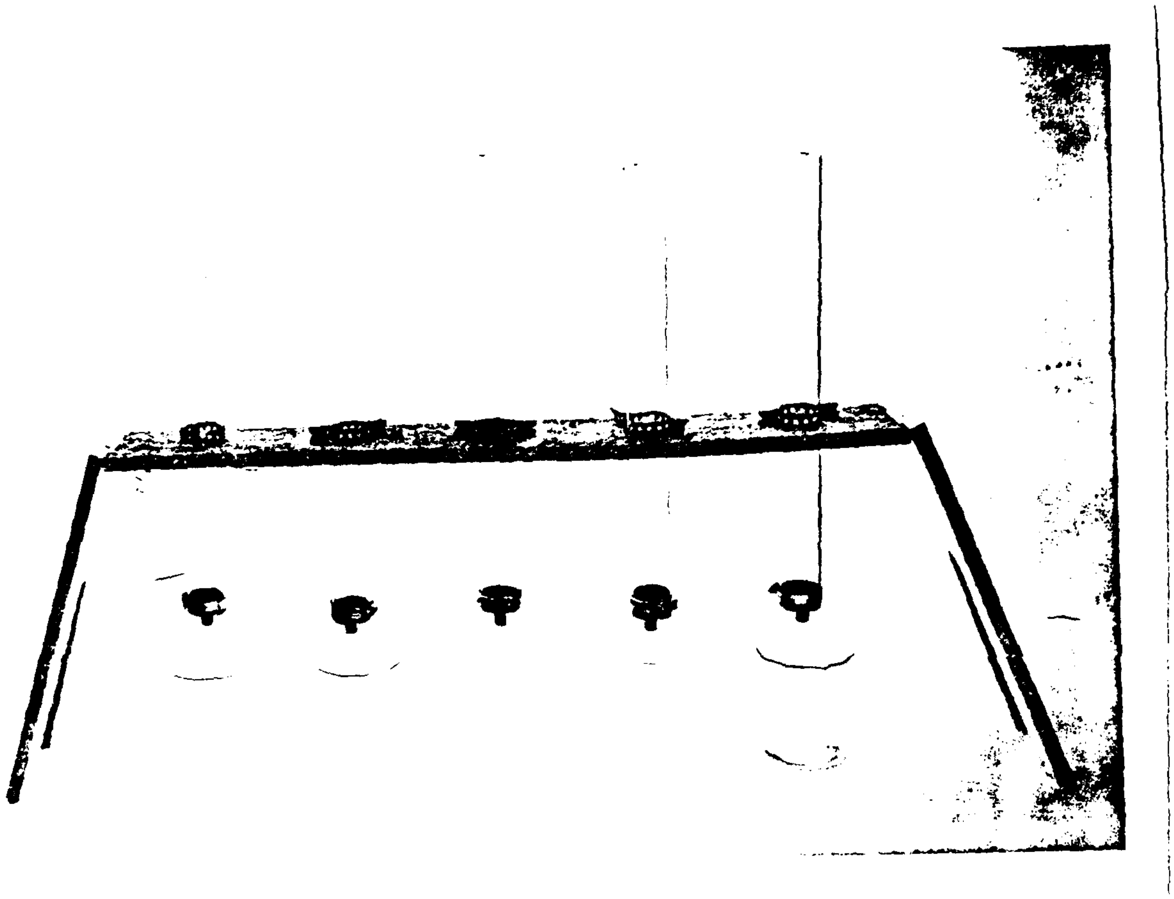

Figure 1. Batch mixed media test kit without media (test kit no. 1).

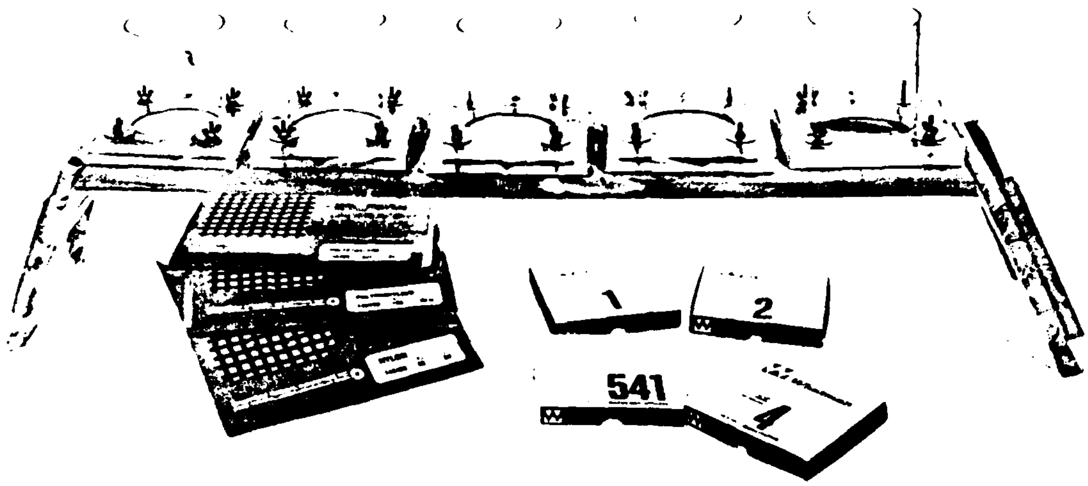

Figure 2. Batch stacked filter test kit (test kit no. 2).

2. Turbidity and temperature were recorded for the sample.

3. The sample was dosed with polymer and vigorously mixed for 15 seconds.

4. The sample was then poured into the top of one of the columns. A similar graduated beaker was used to collect the test kit effluent below.

5. Filtration rate was determined by noting the time to fill up 100 ml increments in the collecting beaker. Testing was terminated when some fixed amount of effluent was collected, or after five minutes had passed, whichever came first.

6. Effluent turbidity was then measured in the collected effluent sample.

Separate columns were used for the various polymer doses tested in the range of 0 to 5 mg/l. The units were cleaned after use by flushing with clean water. Filter papers were replaced and the mixed media filters were backwashed before subsequent use.

In a series of preliminary tests, the two test kits were operated side-by-side with the pilot filter for a day each at seven water bodies in the general vicinity of Milwaukee. Identification of sites and influent turbidity ranges tested are listed in Table 2. The filter was mounted on the back of a small truck as shown in Figure 3 and 4. Portable, submersible pumps were used to feed the filter from the water course and for backwash using clean filter effluent stored in a portable tank. The pumps were powered by a generator mounted on the truck. Figure 5 shows the method for preventing pickup of bottom materials by the influent pump; a submerged plastic drum was used to keep the suction off the bottom of the water course.

During the course of each test day, the filter was run for short periods (in the vicinity of an hour) at a series of polymer doses. The filter was backwashed between each condition. Because of the low influent turbidity conditions of the rivers and the short run times, differential pressure across the pilot filter could not be used as a measure of filter performance at the various polymer doses. Effluent turbidity from the pilot filter was the sole filter performance variable used in the evaluation. Nor was this found to be a sensitive indicator of the effect of changing polymer doses. Filter effluent turbidity varied in a very narrow range for all of the tests conducted. Although the effect on effluent turbidity could be readily seen when the filter was changed from no-polymer to some polymer, the point at which overdosing occurred (if, indeed, it occurred) and its effect on the filter escaped recognition in these tests.

Transient Nature of the Test Kit Data--
Pouring a small, fixed volume of fluid through a test kit filter produced a completely transient result. The flow rate through, and the pressure drop across, the filter test kits varied from instant to instant. These

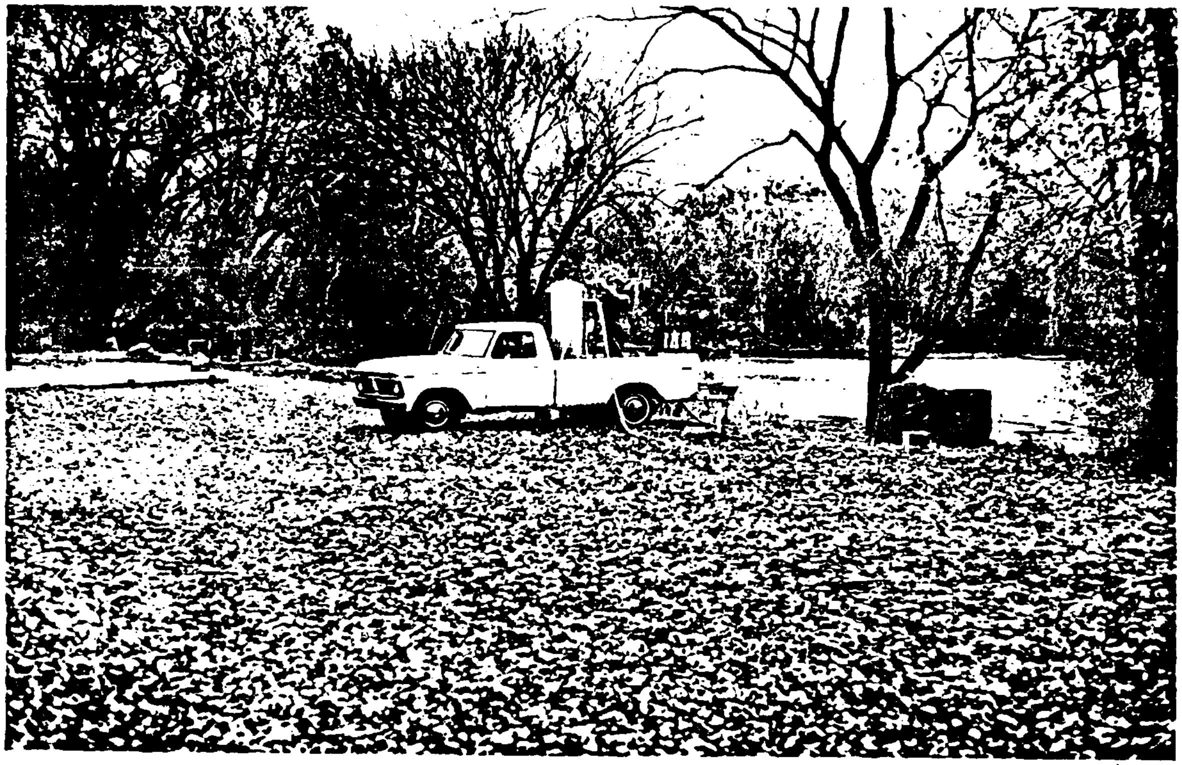

Figure 3. Test kit investigation at the Milwaukee River.

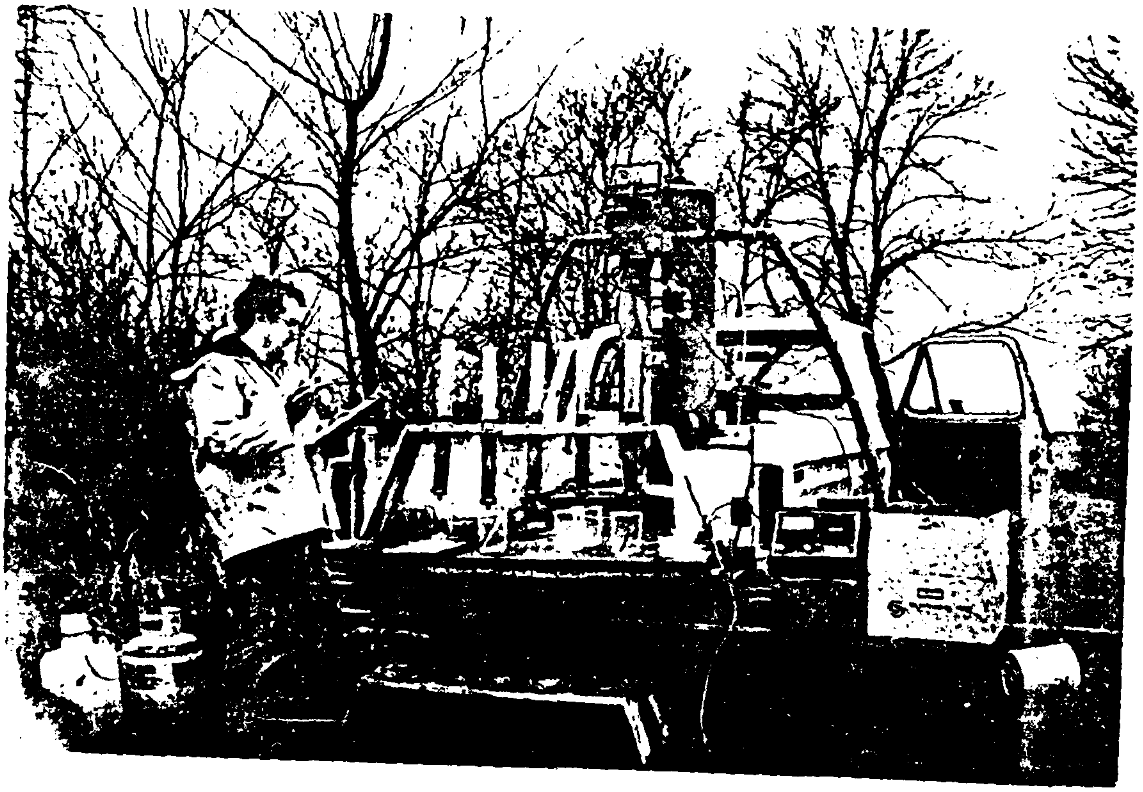

Figure 4. Gathering data from test kit no. 1.

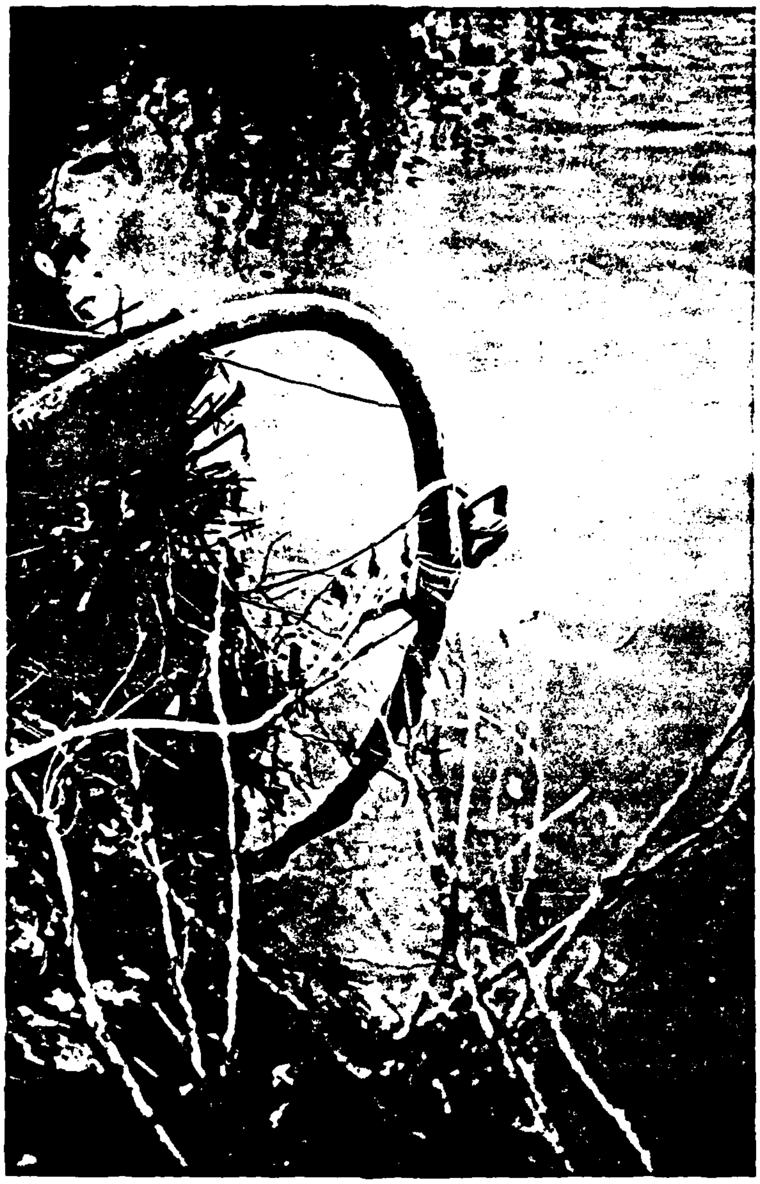

Figure 5. Typical influent pump placement, test kit investigations.

TABLE 2. DESCRIPTION OF WATER BODIES TESTED

Name	Influent turbidity range, FTU
Fox River Marsh	2.9 - 9.9
Tichigan Lake	4.5 - 6.7
Menomonee River	8.2 - 9.2
Milwaukee River	7.6 - 10.0
Root River	11.0 - 16.0
Limestone Creek	9.0 - 23.0
Pewaukee River	15.0 - 42.0

variations were caused primarily by the decreasing pressure head as fluid flowed through the filter, as well as by the turbulence associated with the test kit filling process. In the case of the stacked filter papers (test kit no. 2), after an initial surge the velocity through the filter soon slowed to a trickle as more pore spaces in the filter became clogged. There was a notable decrease in effluent turbidity as the flow slowed down, no doubt due to increased efficiency of the filter caused by the buildup of particulate.

Attempts were made to determine whether polymer dose affected the transient measurements of the test kits to the extent that they could be used as predictors of pilot filter performance. The easiest of the transient variables to measure was filtration rate; only a stopwatch and the transparent, graduated effluent beaker were required to gather data.

Effluent turbidity from the test kit was much harder to measure, except as a composite sample. The decision on how much effluent to composite was complicated by the fact that not all of the influent passed through the test kit in a reasonable length of time. This problem was especially severe in the case of test kit no. 2, stacked filter papers. Where 600 ml (out of 1000 ml influent) were sought in the effluent sample, for example, the flow would sometimes slow to a trickle at 500 ml after several minutes and require a long time to produce the final 100 ml. In certain other tests there was no trouble getting 600 ml in a reasonable length of time. Since the effluent turbidity of the composite sample was found to decrease with time, volume sampled became a complicated but important consideration. However, simplicity in the test kit required the standardization of some procedure and finally a procedure was adopted which included both volume and time limits. Using those constraints, the composite sample may consist of a full 600 ml sample or a sample of lesser volume which had exceeded the time limit. The "arbitrariness" of this procedure added more variability to the measures.

Simulation of Filter Operation--
Even more of a concern than the transient nature of the test kit measurement variables was the serious doubt that flocculation within the filter and depth filtration were being simulated by these methods. The mixed media (coal, silica, garnet) were not submerged during the tests; the filter started and finished in an air-filled condition. It is doubtful that the particle-media bonds, which theory indicates are strengthened by the polymer, were properly formed and maintained by fluid "tumbling" through the media. Nor were the stacked filters successful in distributing the particles among a number of sequential collecting filters; most particles were removed by the first filter in the series.

Results and Conclusions from the Field Evaluations--
Just as head loss did not show significant differences among the various polymer doses for the pilot filter because of low turbidity conditions and the limited length of the test runs, nor did a comparable variable in the test kits, i.e., volume filtered per unit of time, show any significant differences among polymer doses. Effluent turbidity was thus isolated as the variable upon which to draw correlations between test kit and pilot filter. In only several cases among those tested were significant correlations found and the strength of those correlations was site specific.

Based on the above evaluations and findings the following decisions were made:

1. That the filter kits be run in steady state rather than batch modes to remove the undesirable transients in the measurements and to attempt to more closely simulate pilot scale filter performance.

2. That a wider range of turbidities be tested.

3. That the performance of the pilot filter, both differencial pressure and effluent turbidity, be studied throughout entire filter cycles.

4. That a more sensitive indicator than filter effluent turbidity be sought to help establish optimum polymer dosage.

The principle effect of the above decisions was to permit more complexity in the test kit in order to achieve better correlations. Experience had indicated that the simplest methods conceivable did not hold out the promise of producing valid and repeatable results. On the other hand, the added complexity would not necessarily have to be substantial and the resultant test kits could still satisfy the evaluation criteria in large measure. Although more complex in their construction, a second generation of test kits were sought that would still be simple to operate.

SECTION 3

NEW TEST KITS AND EVALUATION STRATEGY

SELECTION OF NEW TEST KITS

For the multi-media test kit (test kit no. 1), the change from batch operation and gravity feed to pressurized flow under steady state was rather easy to accomplish; however, for the stacked filter paper test kit (test kit no. 2) it would not have been. The small diameter multi-media columns were easily converted to pressure flow by replacing the plexiglass columns with transparent plastic piping and capping the columns, whereas the large diameter filter paper test columns would have required the design of special media separators and supports. Because of these necessary design changes and the fact that earlier attempts to simulate pilot filter operation by distributing the filtered particulate among a series of surface filtration steps in the test kit had been unsuccessful, the stacked filter test kit was dropped from the project at this time in favor of concentrating the research on the more promising multi-media filter test kit. This latter offered the possibility of incorporating interface monitoring, i.e., monitoring of pressure and turbidity at the coal/silica and silica/garnet interfaces. It was thought that interface monitoring could possibly be useful in identifying parameters of filter performance which may be more sensitive to polymer dose than effluent turbidity.

Whereas one of the two experimental test kit approaches was now dropped (test kit no. 2), another one that was originally considered - flocculation in a beaker followed by sedimentation and/or filtration - was reintroduced. The only change from before was that acceptance of some degree of mechanization (the multi-media test kit required a battery powered pump) now allowed the use of powered mixer/flocculators which would provide the needed consistency in applying the mixing action.

TESTING FACILITY

It was further decided that the lakes and streams around Milwaukee would not be suitable for testing a wide range of influent turbidities (the Project Officer said that influent turbidities of the full scale water treatment system could range from very low to well over 100 FTU) unless some measures were taken to enhance the naturally occurring turbidity of these water courses, e.g., introducing turbulence in the water course to resuspend settled materials or adding turbid materials. The added complexity expected with controlled turbidity experiments in a field situation as well as the desire to run full cycle filter tests to study time and pressure buildup effects led to the decision to move the testing to an outdoor location immediately adjacent to the Rexnord Environmental Research Center.

The mobile test apparatus had been a drawback to the quantity of data which was gathered in a day's time. Each day's activities had included travel, setup, testing, takedown and travel. The sites chosen were unprotected, i.e., it was not secure to leave the equipment set up overnight. On the other hand, the Rexnord site was protected, had electrical and fresh water supplies, and was immediately adjacent to shop and laboratory facilities.

TEST INFLUENTS

Three test influents were selected to span the range of particles which would probably be encountered in a full-scale operation: clay alone, silt alone, and silt and clay combined.

Clay

The clay was a commercial grade of Southern bentonite. The size of the clay particles was 60 to 92 percent less than 200 sieve size. The chemical composition of the clay included: SiO_2 - 64.17 percent; Al_2O_3 - 17.40 percent; Fe_2O_3 - 4.81 percent; MgO - 3.90 percent; CaO - 1.48 percent; K_2O - 0.48 percent; Na_2O - 0.21 percent. The clay was mixed with tap water to produce test influents in two turbidity ranges, 20 to 30 and 90 to 110 FTU. Suspended solids were measured throughout the range of turbidities tested and found to be directly proportional to turbidity (Figure 6).

Silt

The silt used was of a very fine consistency, gathered near the outfall of a lagoon. To collect the fine silt, turbulence was created in the lagoon and turbid fluids were removed with a submersible pump. The pump was suspended far enough above the bottom to prevent drawing in bottom materials and fast settling solids. The fluids were transported to the Rexnord test facility in barrels. Before testing, the fluids were diluted with tap water to produce the desired turbidity for testing. Due to the logistics of this transport process, the turbidity tested was limited to the range of 26 to 35 FTU. Unlike the clay, the suspended solids for the silty influent were much more variable as can be seen from the statistics of the data taken during the test runs:

	Turbidity, FTU	Suspended solids, mg/l
Range	26-35	50-162
Average	32.50	87.25
Standard deviation	2.78	31.71

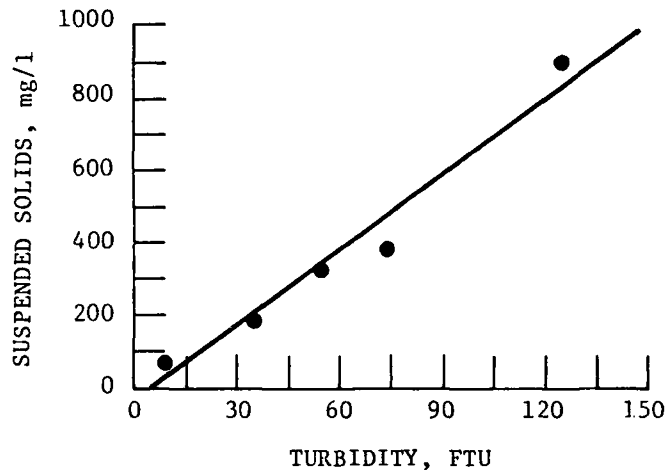

Figure 6. Suspended solids versus turbidity for Southern bentonite clay in tap water.

Silt and Clay

A mixed test influent composed of silt and clay was prepared by diluting the silty fluids to 30 FTU, and then adding clay to raise the turbidity to a test range of 55 to 65 FTU. Because of the silt, the test influent resulting from this combination was also variable in suspended solids:

	Turbidity, FTU	Suspended solids, mg/l
Range	58-60	134-232
Average	59.2	179.2
Standard deviation	1.1	38.8

TESTING APPARATUS

Schematic diagrams of the testing apparatus installed at the Rexnord Milwaukee site are shown in Figure 7 (filtration mode) and Figure 8 (backwash mode). Figure 9 shows the arrangement of the site and Figure 10 shows the test filter. The sequencing valves were removed during the tests for fully manual operation and flow control through a flowmeter. An orifice and a series of elbows were installed upstream of the filter to replace the mixing turbulence associated with these valves. Figure 11 shows the operator's test station in which the turbidimeter and polymer feed pump were located.

The influent to the filter was mixed and stored in a portable swimming pool. The fluids were kept mixed with a propeller mixer and recirculating pumps. The mixing was thorough but gentle to provide uniform turbidity while allowing large particles to settle. An arrangement such as was used in the previous field experiments (Figure 5) was used to prevent intake of settled materials by the influent pump.

Temperature was not controlled during the tests, but monitoring revealed that it varied narrowly between 15 to 20°C. The same influent fluids were used for both the pilot filter influent and the test kits.

Pilot filter influent and effluent turbidities were measured with a Hach 2100A turbidimeter. Filter flow was measured by a totalizing flowmeter; polymer flow was measured with a rotameter; differential pressure across the pilot filter was measured with a differential pressure gage. Filter influent was supplied to the filter by a centrifugal pump; the backwash pump was also a centrifugal pump. The polymer feed pump was a diaphragm pump.

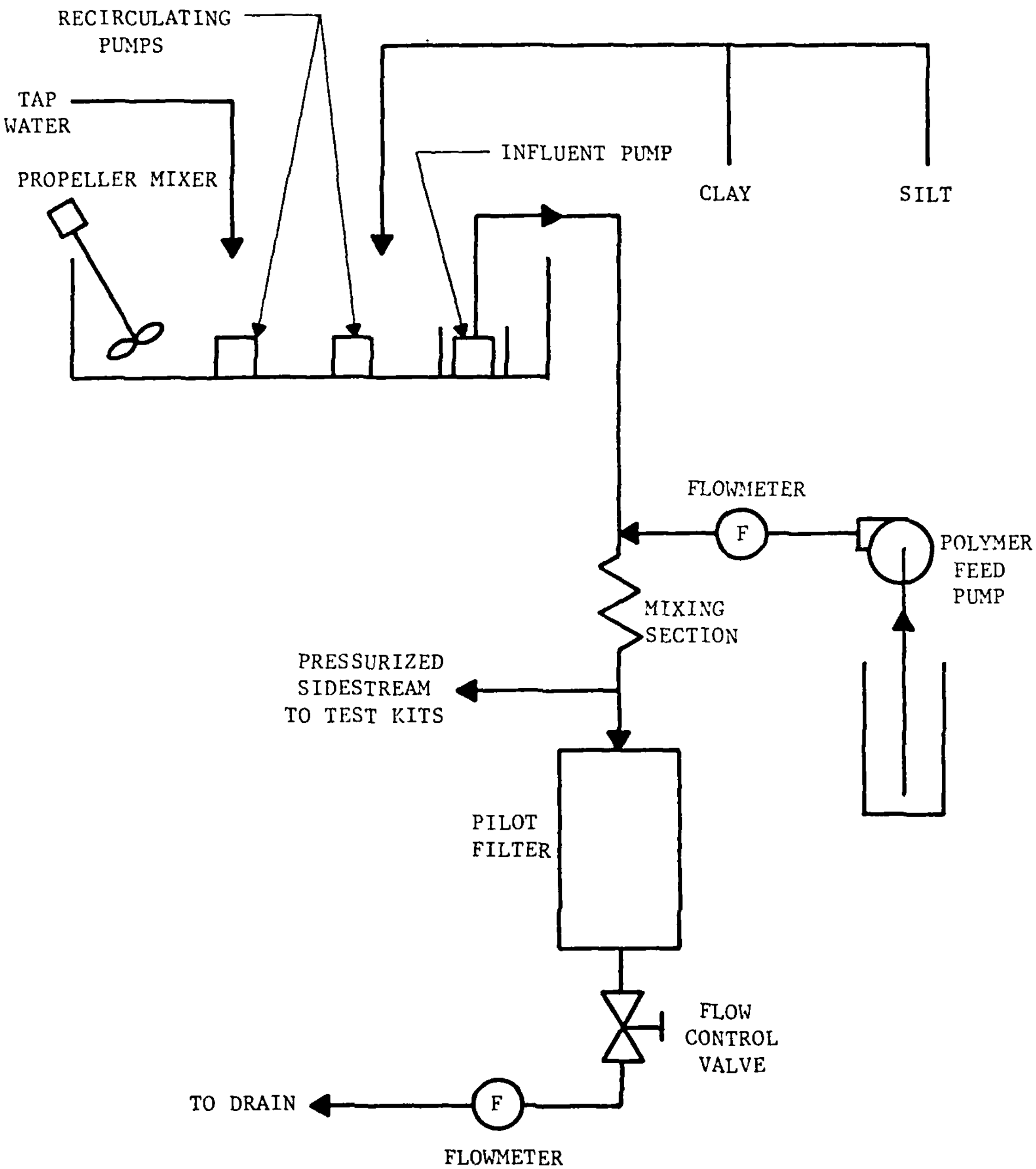

Figure 7. Pilot test filter in downflow filtration mode.

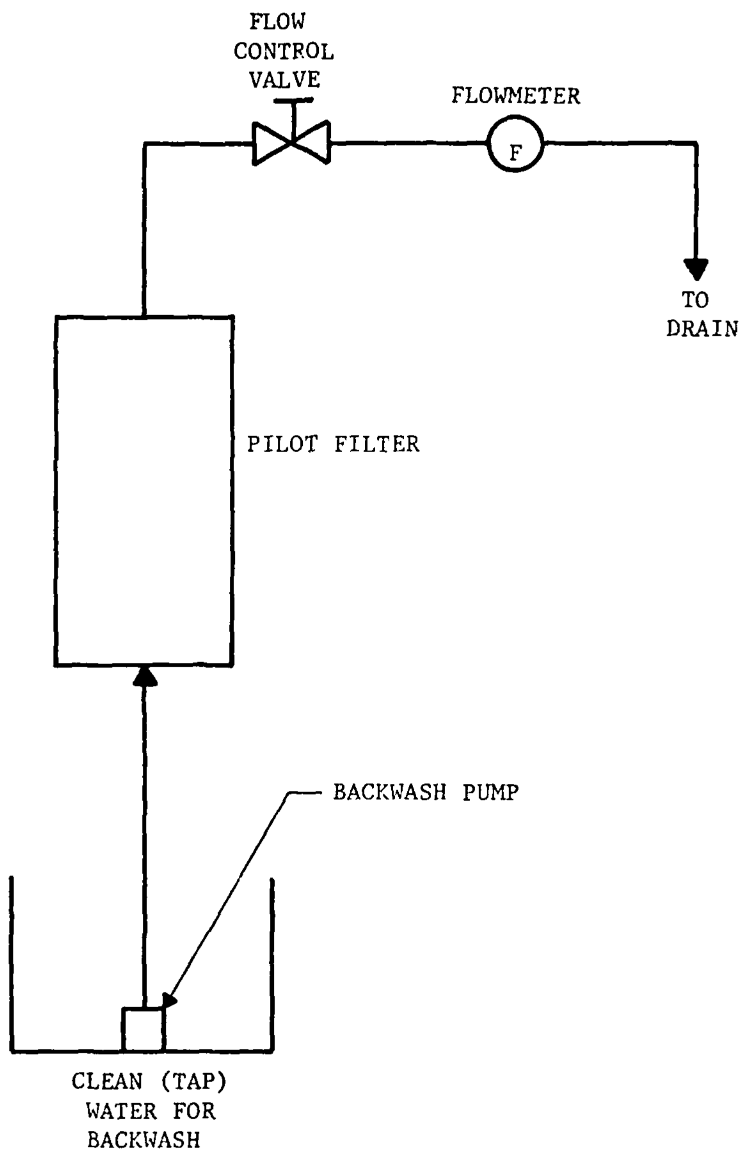

Figure 8. Pilot test filter in upflow, backwash mode.

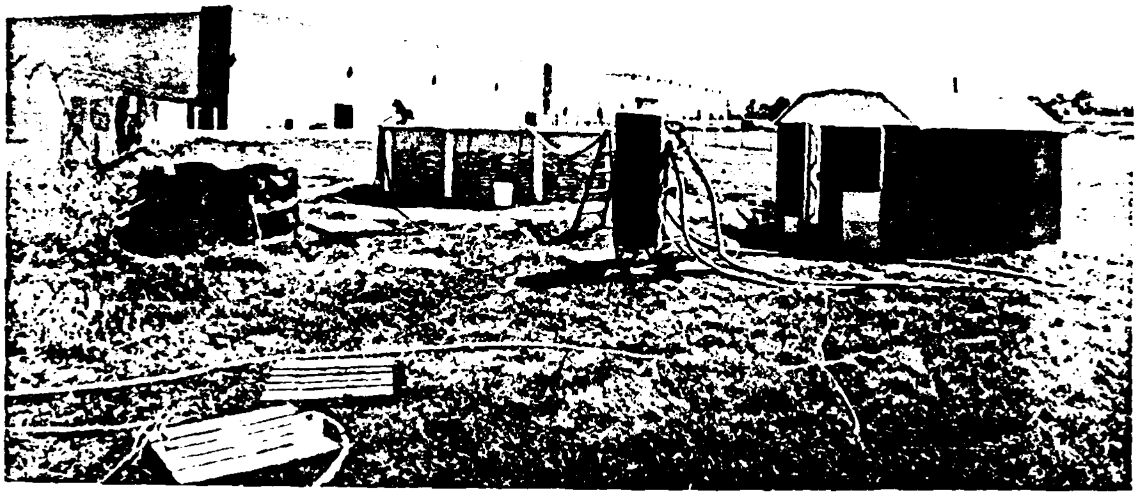

Figure 9. Pilot test facility at the Rexnord Milwaukee site.

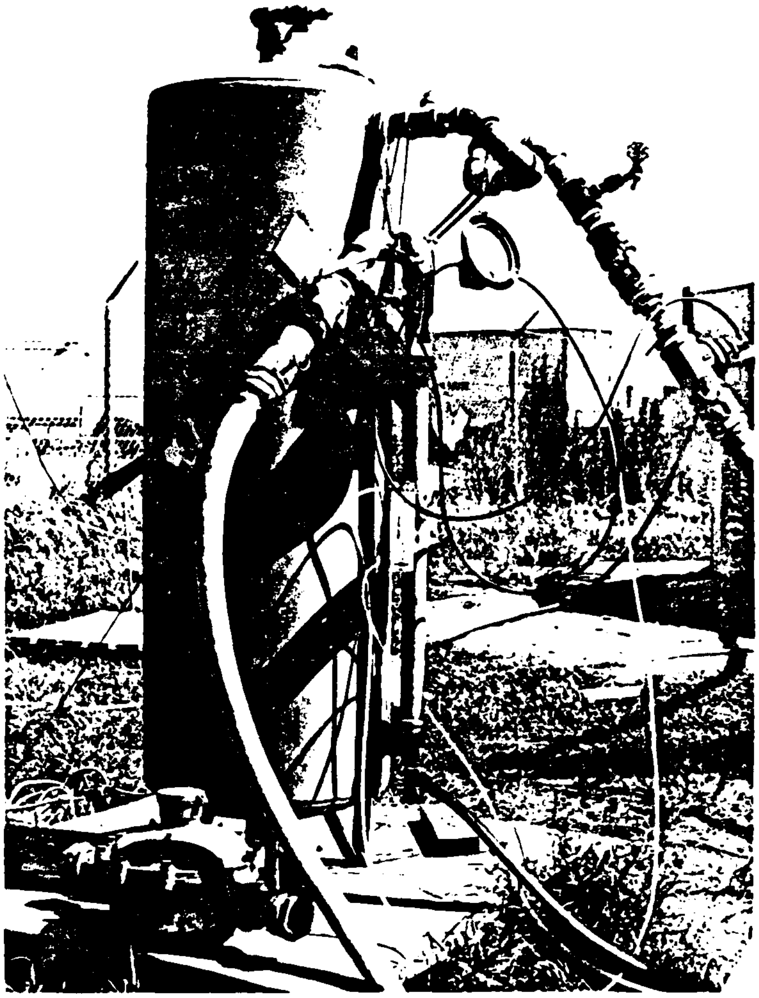

Figure 10. Pilot filter during filtration testing.

Figure 11. Inside the pilot testing station.

SECTION 4

PILOT FILTER PERFORMANCE

TYPICAL PERFORMANCE

Before the effect of polymer dose on filter performance is discussed, typical filter performance curves will be presented for each of the three influent streams tested. i.e., clay, silt, silt and clay. The filter runs to be used by way of example are shown in Figures 12 to 14. On these graphs, effluent turbidity and filter differential pressure are plotted.

The intent here is to discuss trends of the data, not to quantitatively compare the data. Quantitative comparisons are the subject of the latter part of this section.

The data shown here are typical of the pattern of filter performance for each of the filter influent streams, regardless of polymer doses used.

Clay

As can be seen from Figure 12, the effluent turbidity from the filter was low when the backwashed filter was brought on line and it slowly decreased as time went on. Meanwhile, differential pressure increased linearly. After 150 minutes the filter suddenly broke through. The differential pressure gauge was completely insensitive to the breakthrough.

Silt

Figure 13 shows that when water containing silty materials was fed to the filter, the effluent turbidity quickly stabilized at a low value which it maintained for the first half of the filter run. During this period the pressure gradually rose. Shortly after 160 minutes into the run, the rate of pressure rise began to increase dramatically. Effluent quality signaled this change by a slight reduction in turbidity. Termination of the filter run was because of blinding in this case.

Combination Clay and Silt

A combination of clay and silt produced the effect that the filter was subject to both blinding and breakthrough. The graph in Figure 14 shows that halfway through the cycle the signs of blinding failure began to appear in both the pressure and turbidity graphs. However, instead of remaining at a low level as it did for the silty water, the effluent

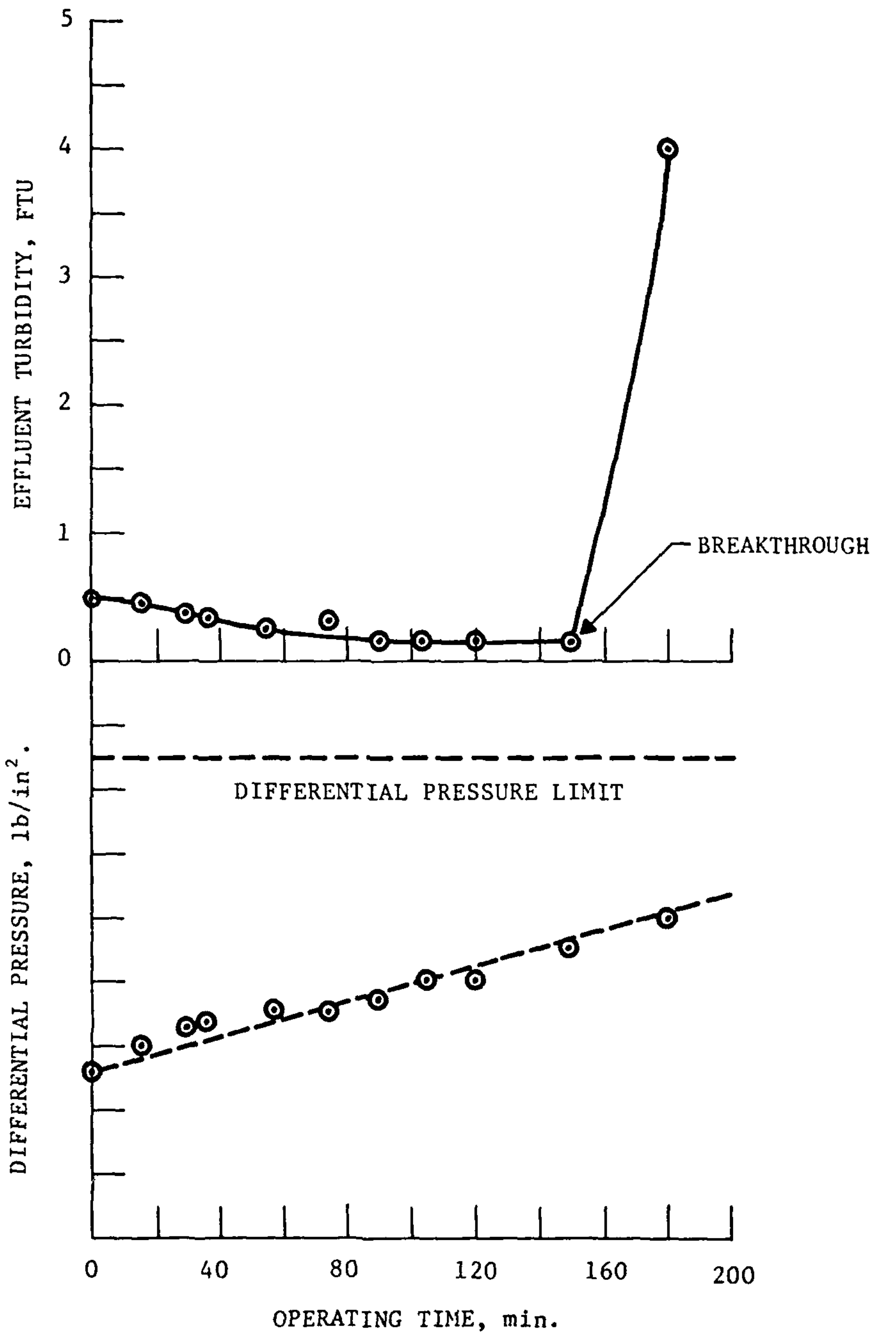

Figure 12. Typical filter breakthrough
when filtering clay.

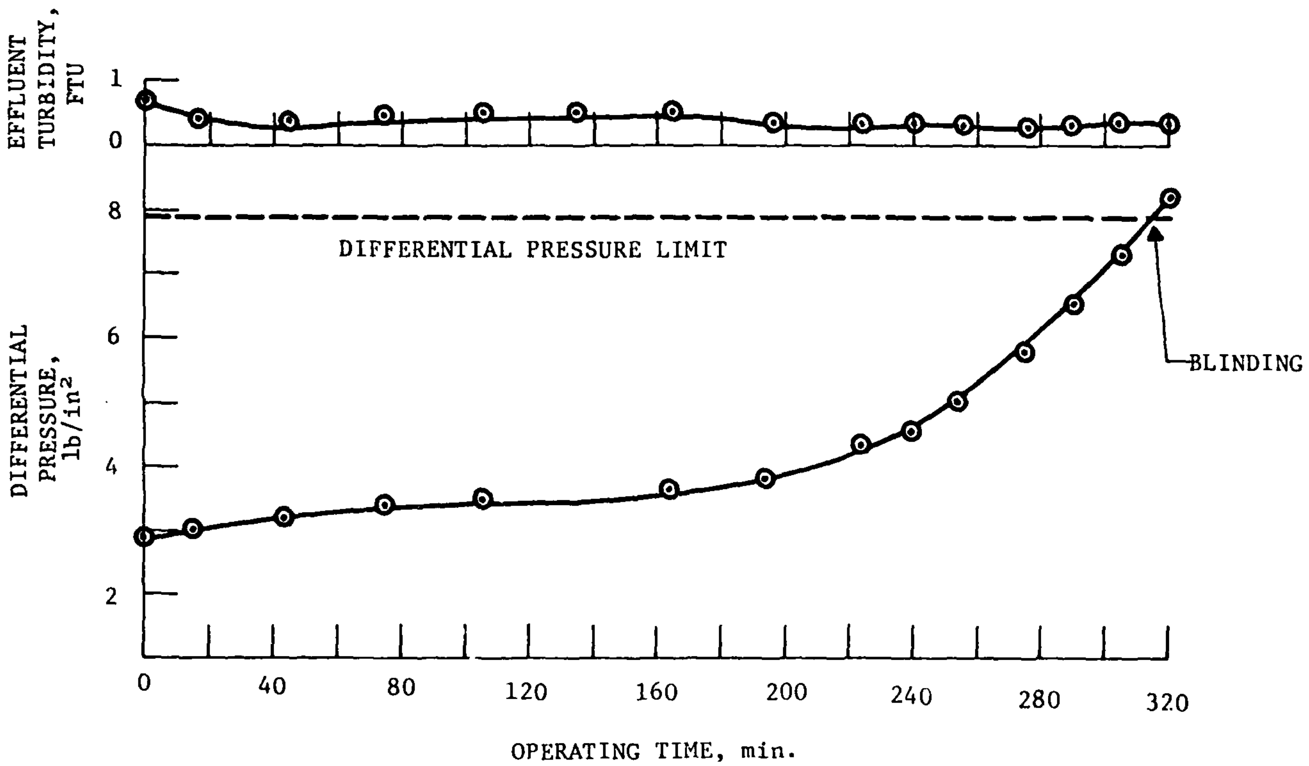

Figure 13. Typical filter blinding when filtering silt.

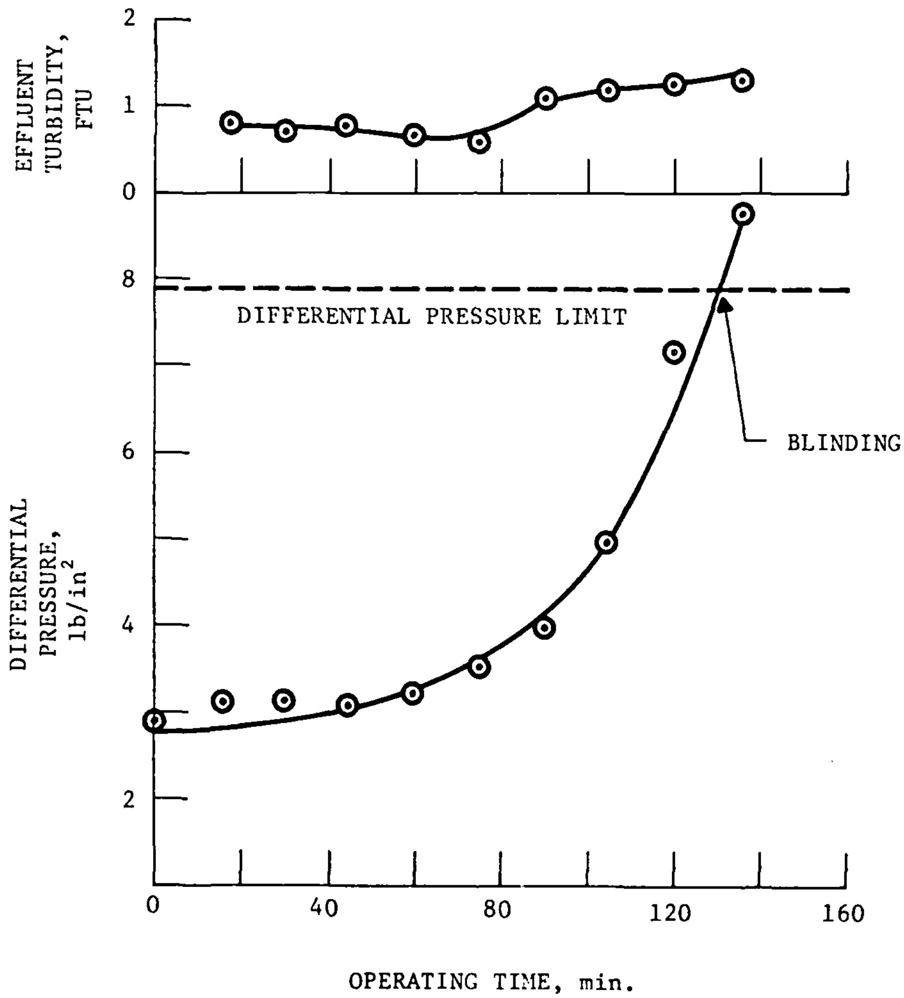

Figure 14. Typical filter blinding and impending breakthrough when filtering silt and clay.

turbidity for the combination clay and silt began to gradually rise, signalling the start of a breakthrough. Blinding occurred before the breakthrough became significant.

Summary of Typical Filter Performance for the Three Filter Influents Tested

1. The removals of particulate matter by the newly backwashed filters were high from the very start; there did not seem to be any break-in period.

2. The cause for terminating the filter run was different for each of the three influents tested:

Influent	Cause for termination
Clay	Breakthrough
Silt	Blinding
Clay and silt	Blinding with impending breakthrough

3. Impending blinding by silty materials was sensed as a significant increase in the rate of pressure rise accompanied by a very small but noticeable dip in effluent turbidity.

4. The differential pressure measurements were insensitive to breakthrough by clay, which occurred very rapidly.

EFFECT OF POLYMER DOSE

The results for the polymer dosage studies are presented in Figures 15 to 18. Three filtration parameters are presented as a function of polymer dose: effluent turbidity, run length, and weight of material captured. The effluent turbidity plotted was the average of turbidity readings during the first phase of the filter run, prior to the onset of failure. Run length was determined as the continuous interval from the time the influent stream began to be fed to the backwashed filter until either breakthrough or blinding caused the run to be terminated. To determine the weight of material captured, suspended solids (SS) values were averaged from several influent and effluent samples taken during the first phase of the filter run, prior to the onset of failure. Weight of material captured was calculated as:

$$\text{Wt (kg)} = [\text{Inf SS (mg/l)} - \text{eff SS (mg/l)}] \times \text{volume filtered(l)} \div 10^6$$

The volume filtered was measured by a totalizing flowmeter from the beginning of the filter run until the termination of the run (at failure or 8 hours).

Each point on these graphs represents a separate filter run; each run began with a newly backwashed filter.

Clay

The effect of polymer dose on filtration parameters was studied at two influent turbidity conditions: 20 to 30 FTU and 90 to 110 FTU. The results are presented in Figures 15 and 16, respectively.

20 to 30 FTU Tests--

Using no polymer, the effluent turbidity was 3 FTU. As can be seen on the top curve in Figure 15, the polymer began to take effect at very low dosages (0.001 mg/l). Effluent turbidity decreased as polymer dose increased until the dose approached 0.01 mg/l, at which point it leveled off. Run length increased linearly with polymer dose and, at a dose of 0.05 mg/l, the run exceeded the eight-hour time limit and was terminated. On the basis of both minimum effluent turbidity and a full eight-hour run time, optimum polymer dosage for this condition was, thus, 0.05 mg/l.

Weight of material captured followed the same pattern as run length. At 0.05 mg/l dose, the weight of material retained by the filter would have approached or exceeded 5 kg, had the run been continued.

90 to 100 FTU Tests--

In this turbidity range, only half the influent turbidity was removed by the filter without the aid of polymer. The lowest polymer dose which could be used was 0.05 mg/l (Figure 16). At any lesser dose, breakthrough occurred almost as soon as the filter was started. Between 0.05 and 5.0 mg/l, effluent turbidity was nearly constant, decreasing very slightly with increased polymer dose.

However, unlike the tests run at lower influent turbidity, run length did not increase with polymer dose until it exceeded the eight hour maximum. Rather, run length increased with polymer dose to some maximum and then fell off. The longest run measured was 150 minutes at a 0.5 mg/l dose, which represents the optimum condition.

Weight of material retained followed the same trend, with 5 kg being the highest weight retained.

Silt

26 to 35 FTU Tests--

Without polymer, the filter produced an effluent turbidity of 5 FTU. The upper graph in Figure 17 shows that effluent turbidity decreased with increasing polymer dose to a minimum in the vicinity of 0.15 mg/l dosage. Doses above this range resulted in a slow, steady increase in effluent turbidity. In the range of dosages at which effluent turbidity reached a minimum, run length was consistently about five hours. Dosing above this range caused run length to begin to fall off. Thus, a dosage of 0.15 mg/l is optimum, primarily based on minimum effluent turbidity.

The weight of silty material retained did not follow the run length data as the clay data did, probably due to the greater variability in suspended solids for different batches of the silt. The weight of silty material

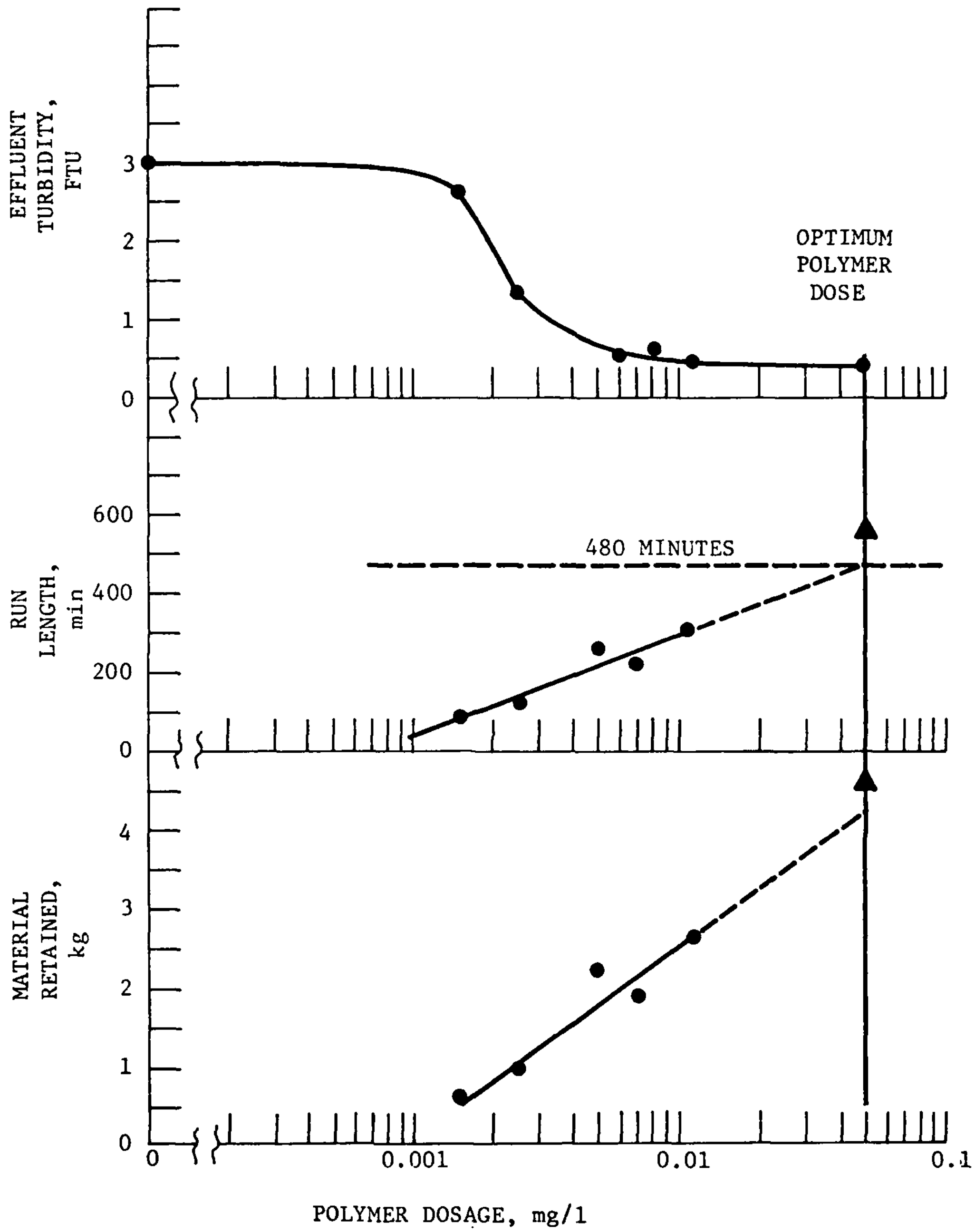

Figure 15. Effect of polymer dose on pilot filter parameters. (Material: clay; influent turbidity: 20-30 FTU).

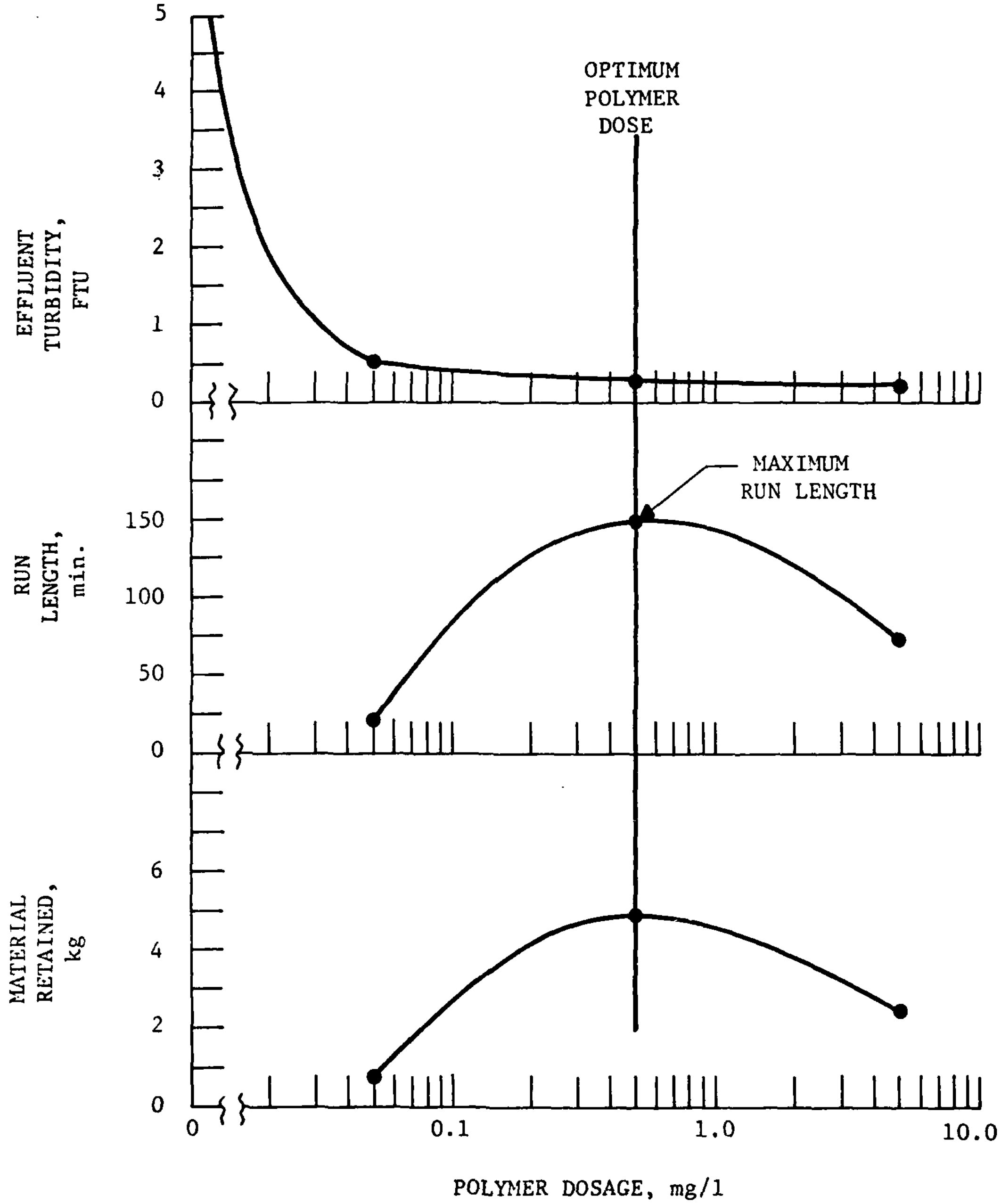

Figure 16. Effect of polymer dose on pilot filter parameters. (Material: clay, influent turbidity: 90-110 FTU).

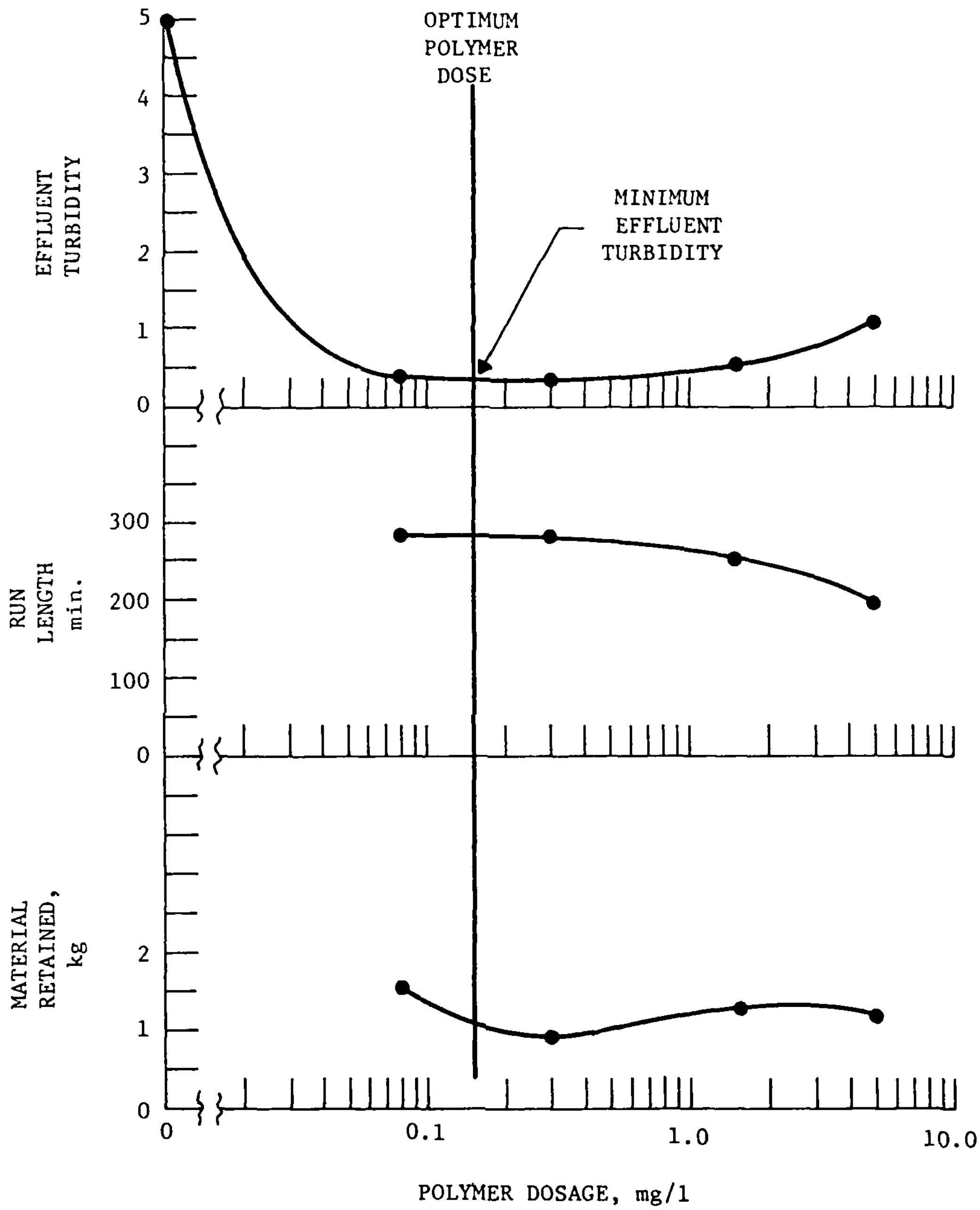

Figure 17. Effect of polymer dose on pilot filter parameters. (Material: silt, influent turbidity: 26-35 FTU).

retained ranged narrowly from 0.9 to 1.6 kg, only a fraction of the clay which the filter could retain before failure.

Silt and Clay

58 to 60 FTU Tests--
Without polymer, the filter produced an effluent with a turbidity of 25 FTU. With polymer the effluent turbidity graph (Figure 18) showed a minimum at the same dosage that the silt tests did. The run length data show that, as increasing polymer dose brought the effluent turbidity to its minimum, run length was decreasing to about 140 minutes. Again, optimum polymer was probably about 0.15 mg/l primarily on the basis of minimum effluent turbidity. Weight of material retained was in the same range as the silt only tests.

Polymer Age

At the beginning of the project, polymer was supplied for the testing program by the Army. This polymer was used during all of the preliminary test work (several months long). New polymer was substituted for the tests reported in the previous section and in the test kit experiments.

Comparison of the data taken with old and new polymers showed that polymer age did not appear to effect filter performance on silty materials but it did show a difference in the clay experiments. Old versus new polymer during clay experiments is compared in Figure 19. Although effluent turbidity was little affected, the run length graph showed a shift. When old polymer was used, much more polymer was needed to achieve maximum run length.

Summary of Polymer Dose Experiments

1. Without polymer, the filter produced a high effluent turbidity from 3 to 50 FTU. With polymer the effluent turbidity was reduced in all cases to less than 0.5 FTU.

2. For each influent stream tested, there were polymer doses or dose ranges which produced the best results. Depending on the influent stream, optimum dosages ranged from 0.05 to 0.50 mg/l.

3. Minimum effluent turbidity would not be the only reason for selecting the optimum polymer dosage. Run length was also significantly affected by polymer dose.

4. The filter was able to hold much more clay than silt before filter failure.

5. The age of the polymer did not appear to adversely affect effluent turbidity. In the case of influent containing large amounts of clay, however, old polymer had an adverse effect on run length.

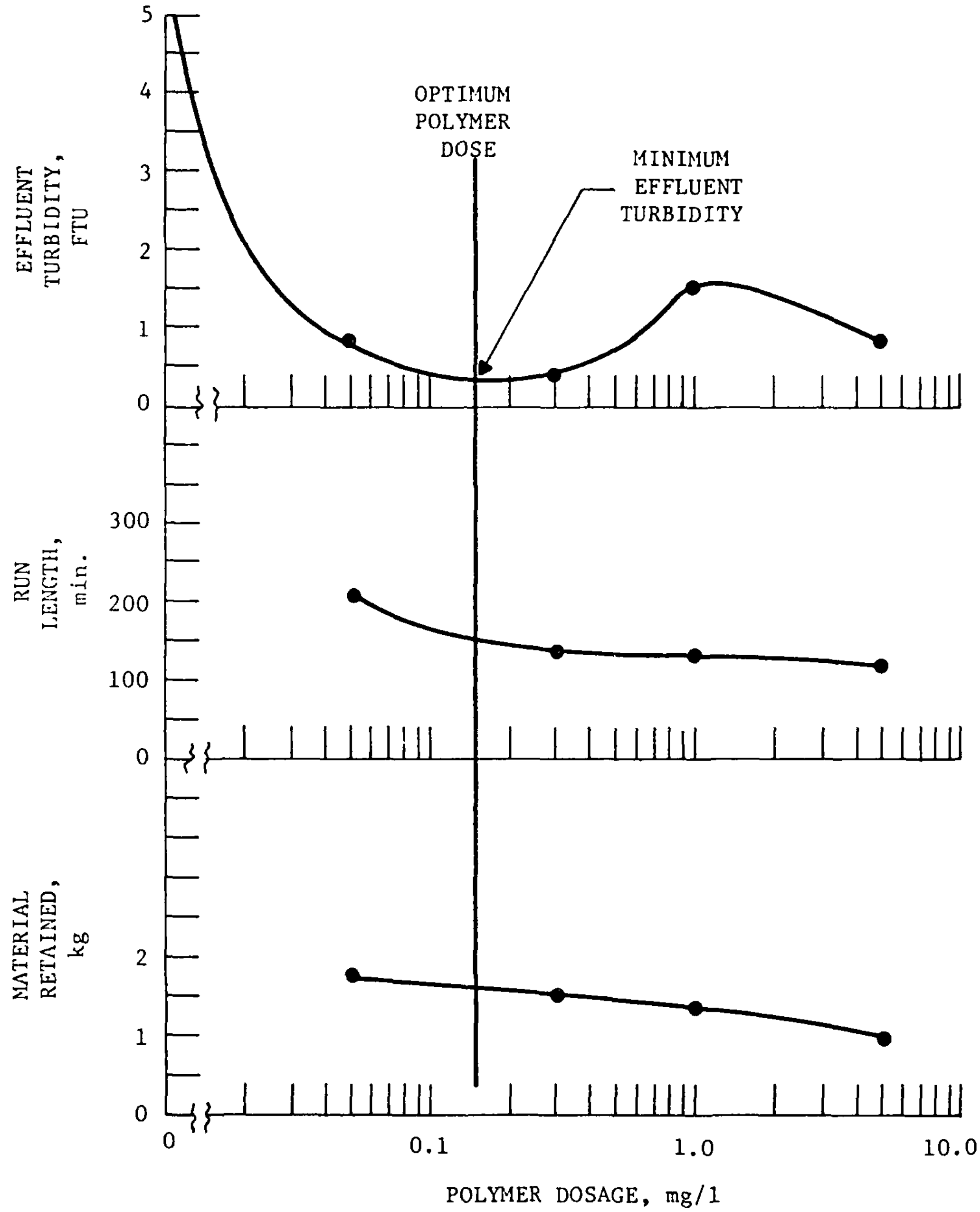

Figure 18. Effect of polymer dose on pilot filter parameters. (Material clay and silt, influent turbidity: 58-60 FTU).

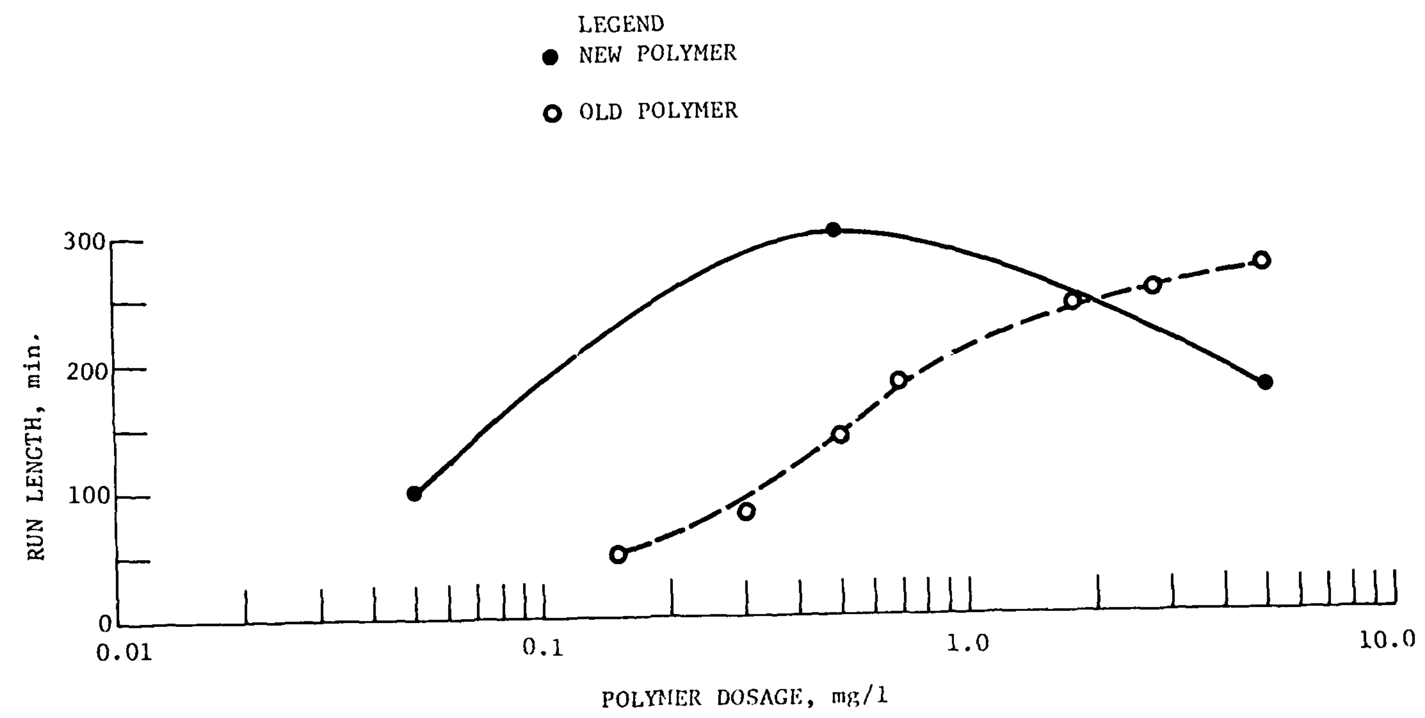

Figure 19. Effect of polymer age on the run length of the pilot filter.

6. A summary of filter information from the pilot filter tests is as follows:

Material	Influent turbidity, FTU	Optimum polymer dosage, mg/l	Conditions at optimum polymer dosage: Effluent turbidity, FTU	Conditions at optimum polymer dosage: Run length, min.
Clay	20 - 30	0.05	0.30	480
Clay	90 -110	0.50	0.30	150
Silt	26 - 35	0.15	0.35	290
Clay and silt	58 - 60	0.15	0.40	135

SECTION 5

INTERFACE MONITORING TEST KIT

DESCRIPTION

The interface monitoring test kit was constructed using three transparent 2.5 inch nominal, schedule 40 plastic pipes, with one media in each pipe (Figure 20). Plastic, threaded adapters were solvent bonded to the top and bottom of each column; columns were attached to ring stands using hose clamps.

The heights of the coal and silica were one-half that of the pilot filter; the height of the garnet was the same as the pilot filter. Plastic chips were placed on the coal and underdrains consisted of the same medium gravel that was used in the pilot filter.

The flow rate through the test apparatus [12 gal./hr (0.012 l/sec)] was monitored with a flowmeter and set to equal the same filtration rate as the pilot filter. The feed to the test apparatus was a pressurized side stream from the pilot filter influent with polymer already added and mixed in (Figure 7). Ports were installed on each column for turbidity and differential pressure measurements.

Preliminary testing indicated that the test apparatus had a break-in period during which filtration was very poor. After a period of running of several hours using influent dosed with polymer, filtration efficiency increased and stabilized. Hereafter, the test apparatus functioned very consistently; the media were backwashed after each test run and the same media were utilized throughout the test program.

POLYMER DOSE PREDICTIONS

Concurrently with the pilot filter tests depicted in Figures 16 to 18, tests were run with the interface monitoring test apparatus. Turbidity curves were developed for each of the three media and it was found that the turbidity emanating from each media stabilized very early in the run, just as the turbidity through the pilot filter did. Turbidity measures in the test kit were made after thirty minutes into each run and were compared to the average turbidity of the pilot filter. Such comparative curves are shown in Figures 21 to 25.

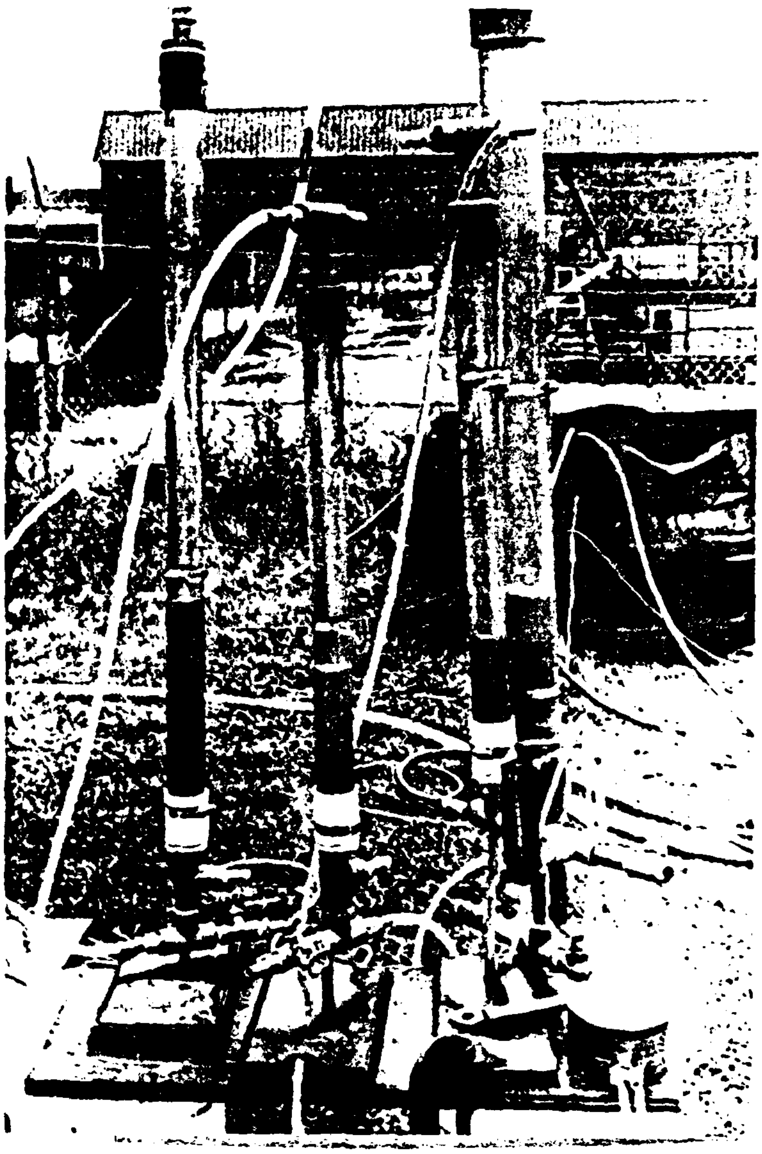

Figure 20. Experimental apparatus for studying interface monitoring (3 columns on left).

Clay (90 to 110 FTU Tests)

Figure 21 shows that the effluent from the garnet section of the test kit (filtration through all three media) closely approximated the effluent turbidity from the pilot filter, which was consistently low in the polymer dosage range of 0.05 to 5.0 mg/l. However, the effluent turbidity of neither the coal nor silica media were constant in this same range. Both showed significant reductions in effluent turbidity as the polymer dose was increased from 0.05 to 0.5 mg/l, indicating greater removals early in the filtration process. Above this dosage range, effluent turbidity leveled off. Although increased removals in the coal and silica sections did not have a noticeable effect on filter effluent turbidity, they did substantially affect run length. The run length for the pilot filter increased from 20 to 150 minutes with an increase of polymer dosage from 0.05 to 0.50 (Figure 22). Above the polymer dosage at which effluent turbidity through the coal and silica appeared to stabilize (0.5 mg/l), the run length began to decrease significantly. Thus, the optimum dosage for the pilot filter (in this case the dosage producing the longest run time) was sensed by the interface monitoring test apparatus as the lowest dosage at which the decreasing effluent turbidity through the coal began to level off.

Silt (26 to 35 FTU Tests)

Figure 22 shows that, like the clay, effluent turbidity through all of the media in the test kit decreased with increasing polymer dosage to some minimum when the influent contained silt. However, unlike the clay, the effluent turbidity for the silt did not remain at the same low value at higher dosages, rather, it began to rise again, resulting in a U-shaped data pattern. Figure 24 shows how sensitively the interface monitoring test kit predicted the effluent turbidity condition of the pilot filter. The scale factor of the two curves plotted is 4:1.

In the upper curve in Figure 23 (effluent turbidity through the coal), the data does not form as smooth a curve as it does for the data from the lower sections of the filter. This was probably caused by the variability in suspended solids of the influent feed water, which would primarily affect the coal section. Had the influent feed been consistent the pattern of the coal data would probably have been a smooth curve, as it was for the clay.

Silt and Clay (58 to 60 FTU Tests)

Figure 24 shows that the combination of clay and silt produced a result similar in most respects to that produced by silt alone. The test kit predicted about the same polymer dose as it did for silt.

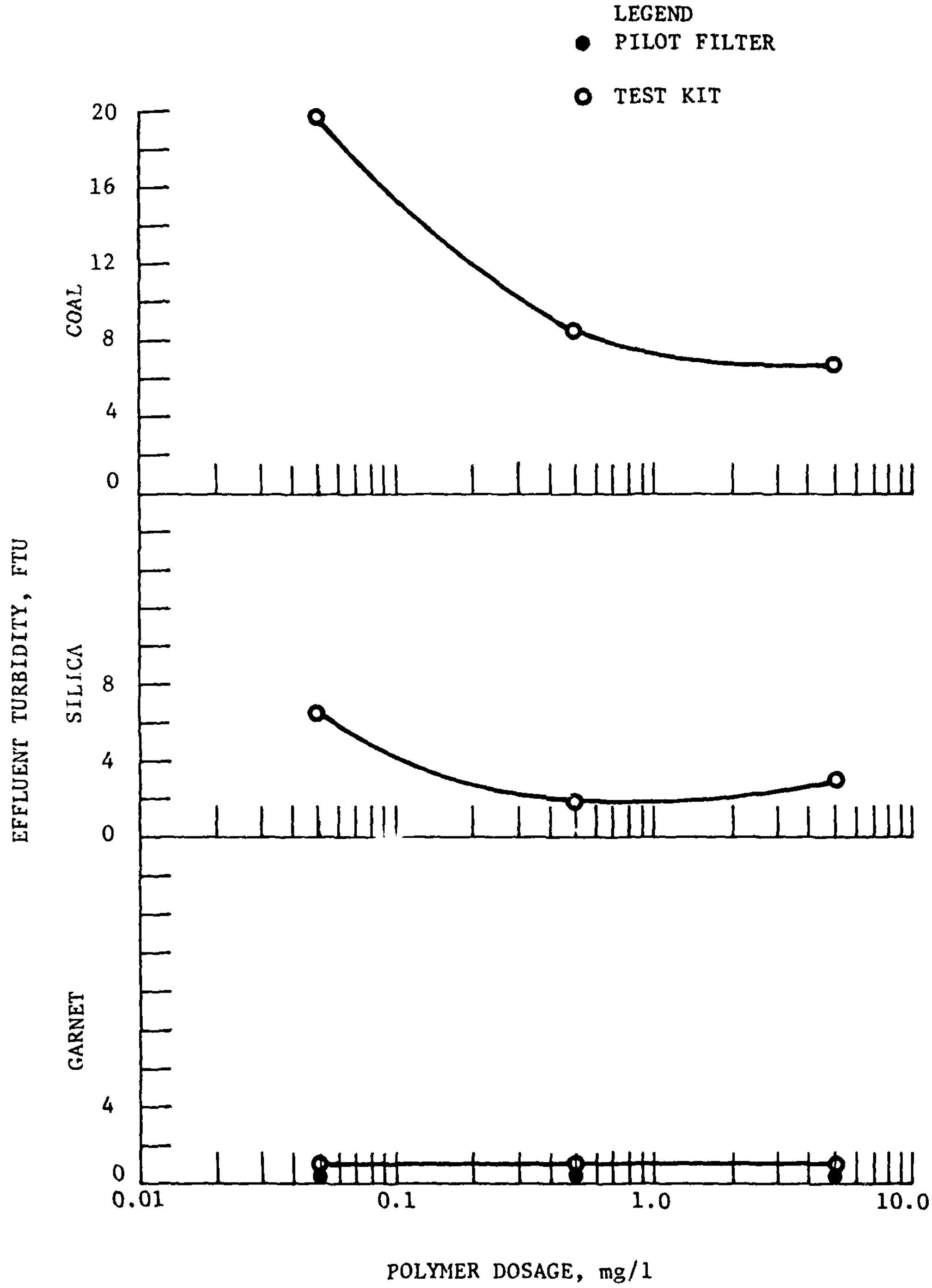

Figure 21. Comparison of effluent turbidity measurements between pilot filter and interface monitoring test kit. (Material: clay; influent turbidity: 90-110 FTU).

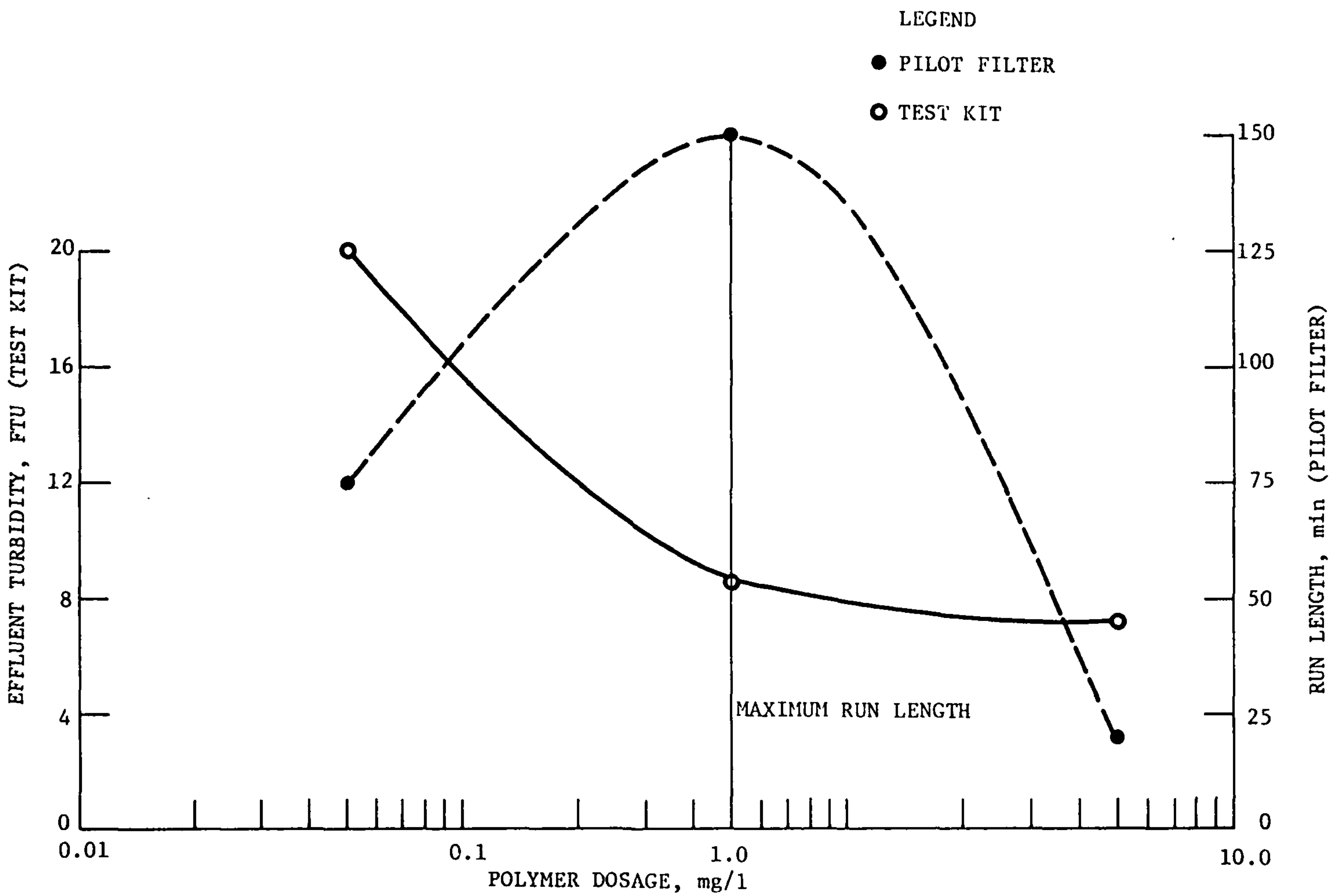

Figure 22. Relationship between effluent turbidity through the coal in the test kit and run length of the pilot filter. (Material: clay; influent turbidity: 90-110 FTU)

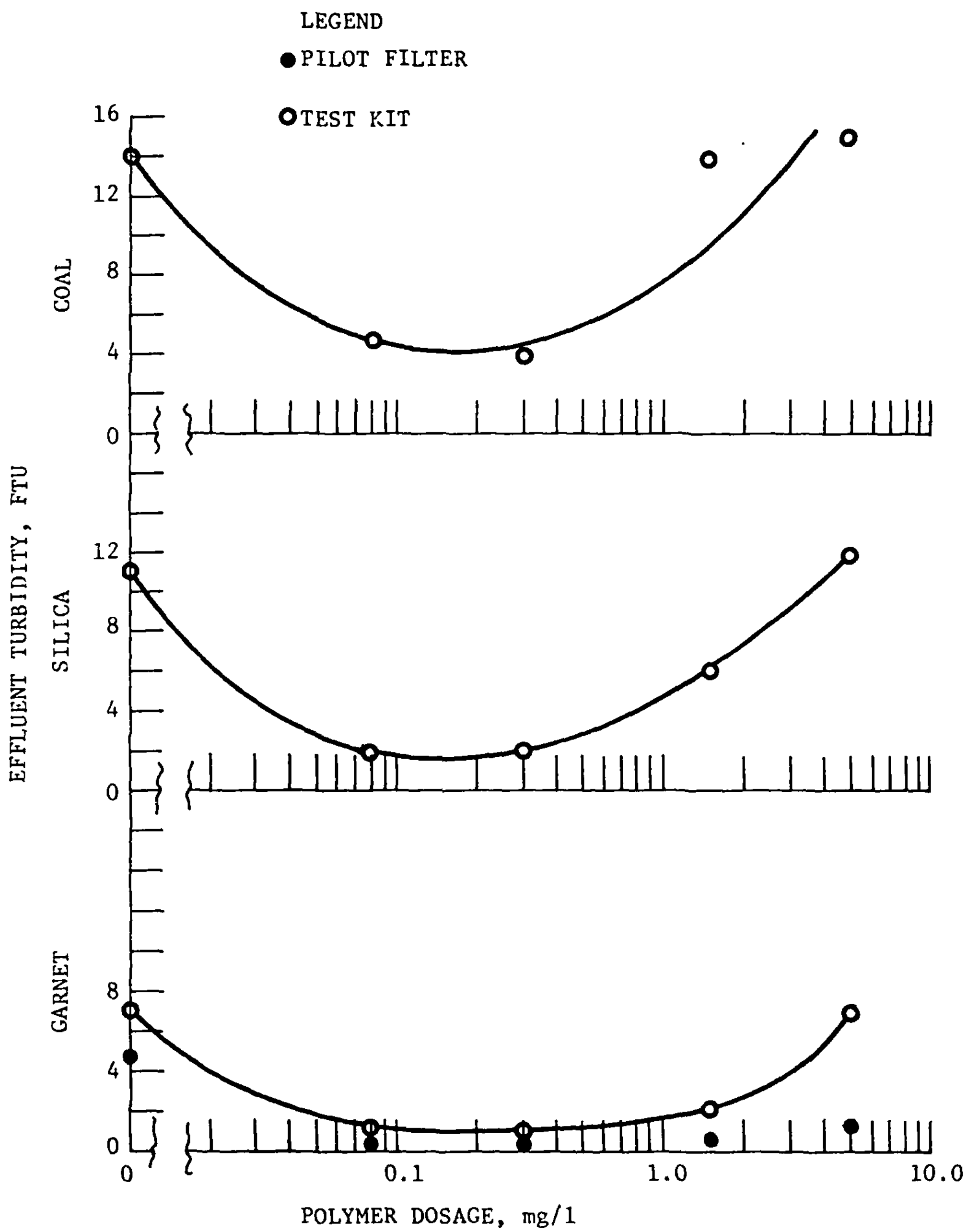

Figure 23. Comparison of effluent turbidity measurements between pilot filter and interface monitoring test kit. (Material: silt, influent turbidity: 26-35 FTU).

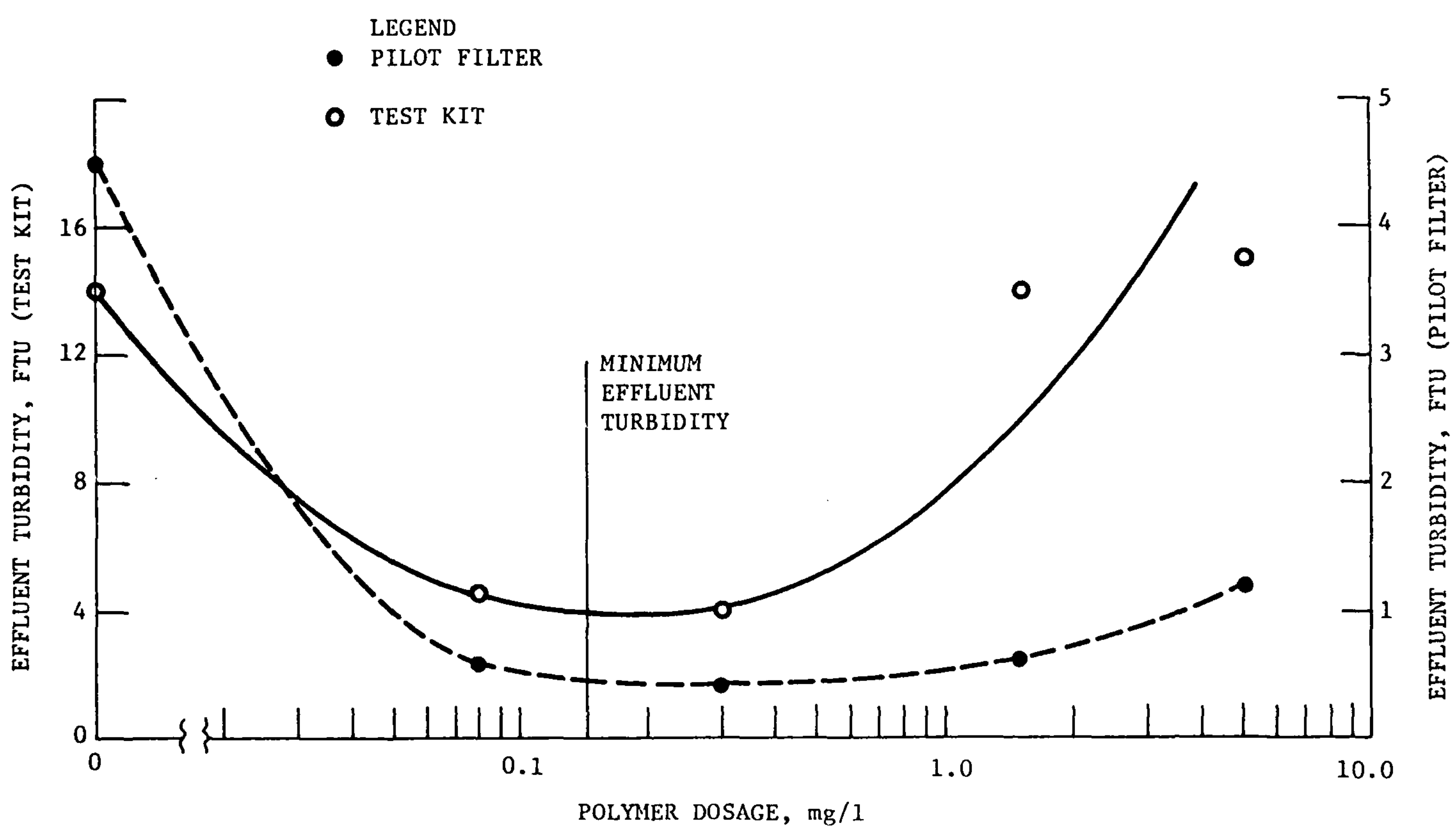

Figure 24. Relationship between effluent turbidity through the coal in the test kit and effluent turbidity of the pilot filter. (Material: silt; influent turbidity: 26-35 FTU).

EFFLUENT TURBIDITY PREDICTIONS

The effluent turbidity from the garnet section of the interface monitoring test kit closely approximated that of the pilot filter. Agreement was especially good in the range of polymer dosages near the optimum; the greater the amount of underdosing or overdosing, the worse the comparisons became.

Figures 21, 23, and 25 show that, except for one data point, the effluent turbidity from the garnet section of the test kit was consistently higher than the effluent turbidity of the pilot filter. This was expected because the media heights for the coal and silica in the test kit were one-half that of the pilot filter.

PREDICTION OF RUN LENGTH

The ports at the inlet and outlet of each column of the test kit permitted monitoring of effluent turbidity and differential pressure across each of the media throughout the filter run. Effluent turbidity and differential pressure across the garnet section produced patterns which were similar to the pilot filter (Figures 12-14).

Differential pressure measurements across each of the media showed that the pressure buildup when filtering silt occurred principally in the coal (Figure 26). Similar measurements could not be made for clay because of a defect in the measurement method. Pressure readings were taken across each of the media in the test kit using a portable gauge. Plugging the gauge in and out did not disrupt the columns when silt was being filtered; it did, however, when clay was being filtered.

The question arose: Could the media depths in the interface monitoring test kit be reduced to the extent that failure would occur quickly in a manner that could be correlated to subsequent failure of the pilot filter. A special multi-media test kit was constructed to explore this possibility and was tested at media depths from 1/8 to 1/2 the total depth of the pilot filter. The test column can be seen as the far right column on Figure 20. The results showed that the time to failure was, on the average,reduced in the scaled down test kit, however, the relationship between run lengths of the test kit and the pilot filter was too variable to represent a useful predictive tool. In a few instances, the pilot filter failed before the test kit.

PREDICTION OF FAILURE MODES

The problem with taking samples from the interface monitoring test kit throughout the filter run when clay was being filtered prevented assessment of the possibility for sensing progressive breakthrough through the filter with test kit measurements. However, the fact that breakthrough was a progressive failure could be attested to by visually monitoring the media through the transparent columns during the test runs. Coal breakthrough was immediately followed by a buildup of material on the surface of the

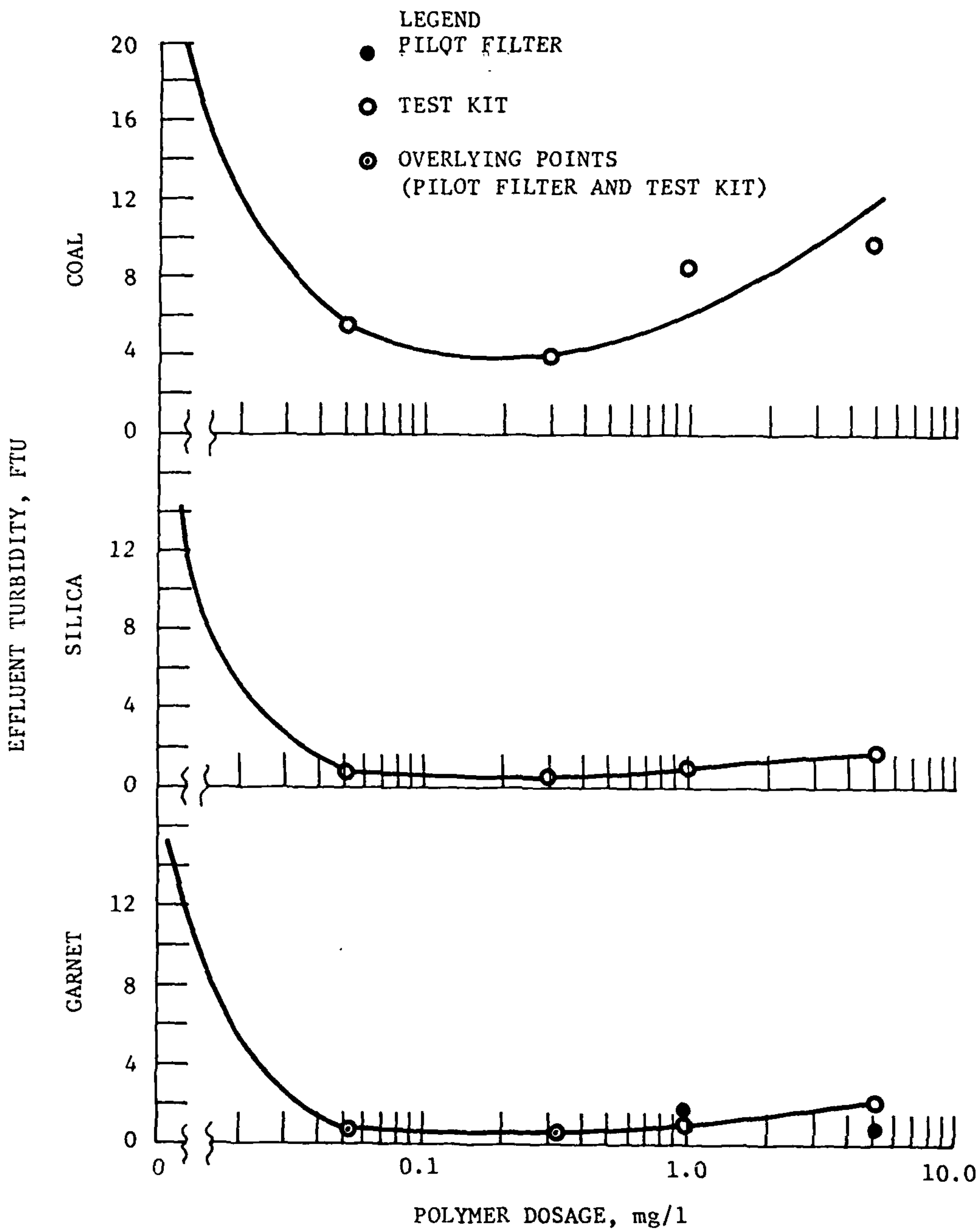

Figure 25. Comparison of effluent turbidity measurements between pilot filter and interface monitoring test kit. (Material: clay and silt, influent turbidity: 58-60 FTU).

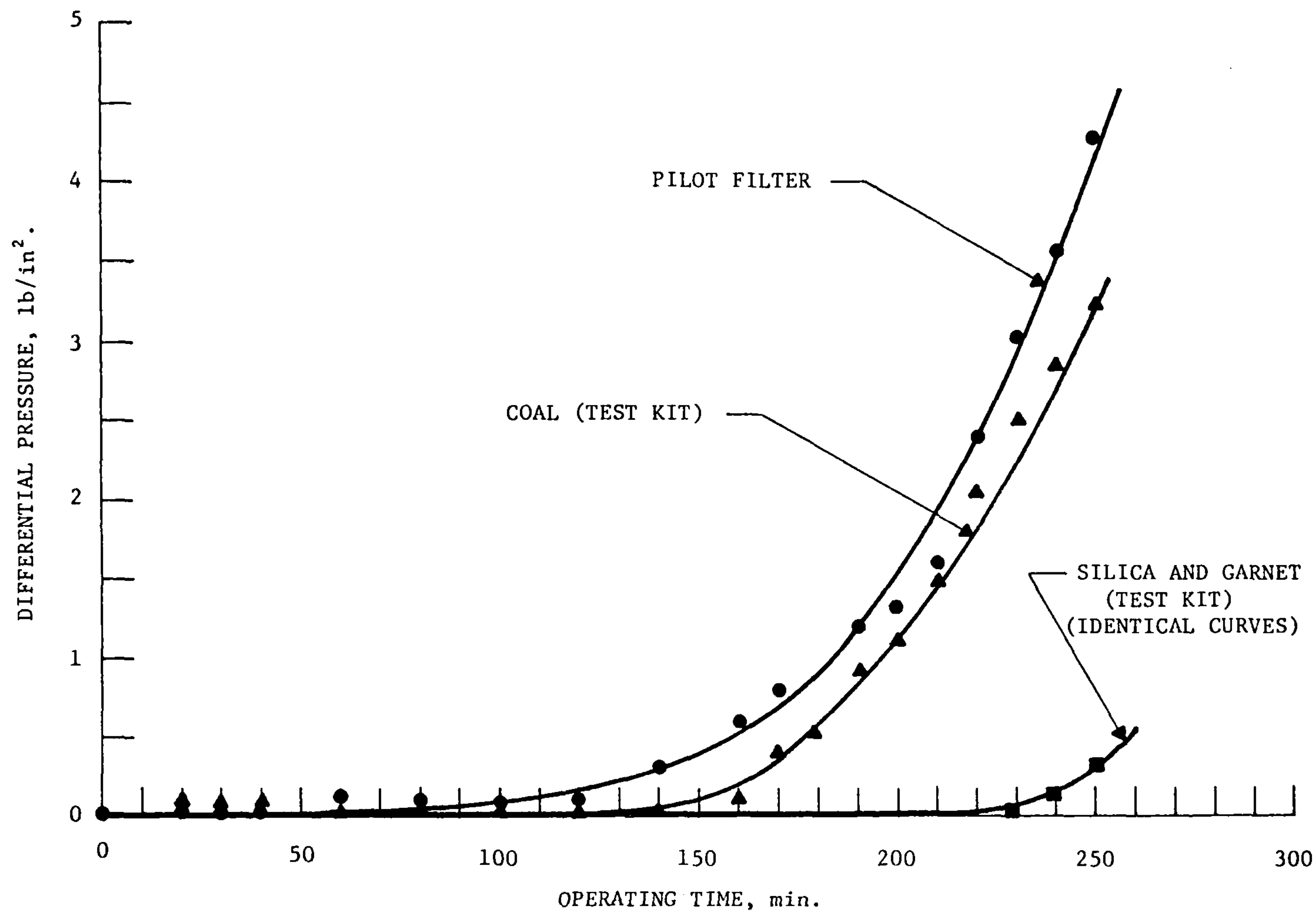

Figure 26. Typical pattern of differential pressure measurements between pilot filter and interface monitoring test kit. (Material: silt).

silica; subsequent silica breakthrough was likewise immediately followed by a buildup of material on the surface of the garnet. Thus, operating side-by-side with the pilot filter, the test kit could provide a visual indicator of impending breakthrough failure. However, the only sure way of quickly sensing breakthrough failures would be the use of an in-line turbidimeter on the outlet of the pilot filter with an automatic shutoff or bypass valve to prevent particulate which has broken through from contaminating downstream processes.

Summary of Interface Monitoring Test Kit Experiments

Polymer Dosage Predictions--

Clay--The optimum dosage for the pilot filter was sensed by the coal section of the interface monitoring test kit as the lowest dosage at which the decreasing effluent turbidity through the coal began to level off. This polymer dosage produced the longest run length in the pilot filter.

Silt--The coal section of the interface monitoring test kit sensitively detected the dosage which produced the minimum effluent turbidity in the pilot filter. This dosage also produced the longest run length.

Prediction of Effluent Turbidity--

The effluent turbidity from the garnet section of the test kit closely approximated that of the pilot filter.

Prediction of Run Length and Failure Modes--

The interface monitoring test kit was not able to reliably give advance warning of an impending failure, nor was it able to predict run length or failure mode. Even using the test kit, differential pressure and effluent turbidity monitoring of the pilot filter is still required to sense failures and protect downstream processing elements against blinding and breakthrough failures.

SECTION 6

BEAKER TEST KIT

DESCRIPTION

The testing apparatus consisted of a six-paddle Phipps and Bird stirrer, 1000 ml beakers, and a filter paper holder (Figure 27). The test steps were as follows:

1. Fill each beaker with a representative 1000 ml aliquot of the influent feed water.

2. Add different, known dosages of polymer to each beaker.

3. Rapidly mix the polymer at maximum RPM for 30 seconds.

4. Flocculate the suspension at a given RPM for 30 minutes.

5. Three alternatives:

    a. Immediately filter an aliquot of the floc suspension through Whatman 541 filter paper.

    b. Allow the suspension to settle for 30 minutes; decant an aliquot from the supernatant and measure turbidity.

    c. Same as Alternative b except that the aliquot of supernatent is filtered through filter paper before the turbidity measurement.

Early exploratory work consisted of determining an appropriate speed of flocculation (Step 4) and deciding among sedimentation and filtration options (Step 5). Influents containing silt and clay were used for the exploratory work.

PRELIMINARY EXPERIMENTATION

Speed of Flocculation

The floc formed when polymer was added to water containing either silt or clay was apparently very strong because flocculation increased as speed increased to the maximum speed of the stirrer (100 RPM). Maximum speed was thus adopted for the experiments.

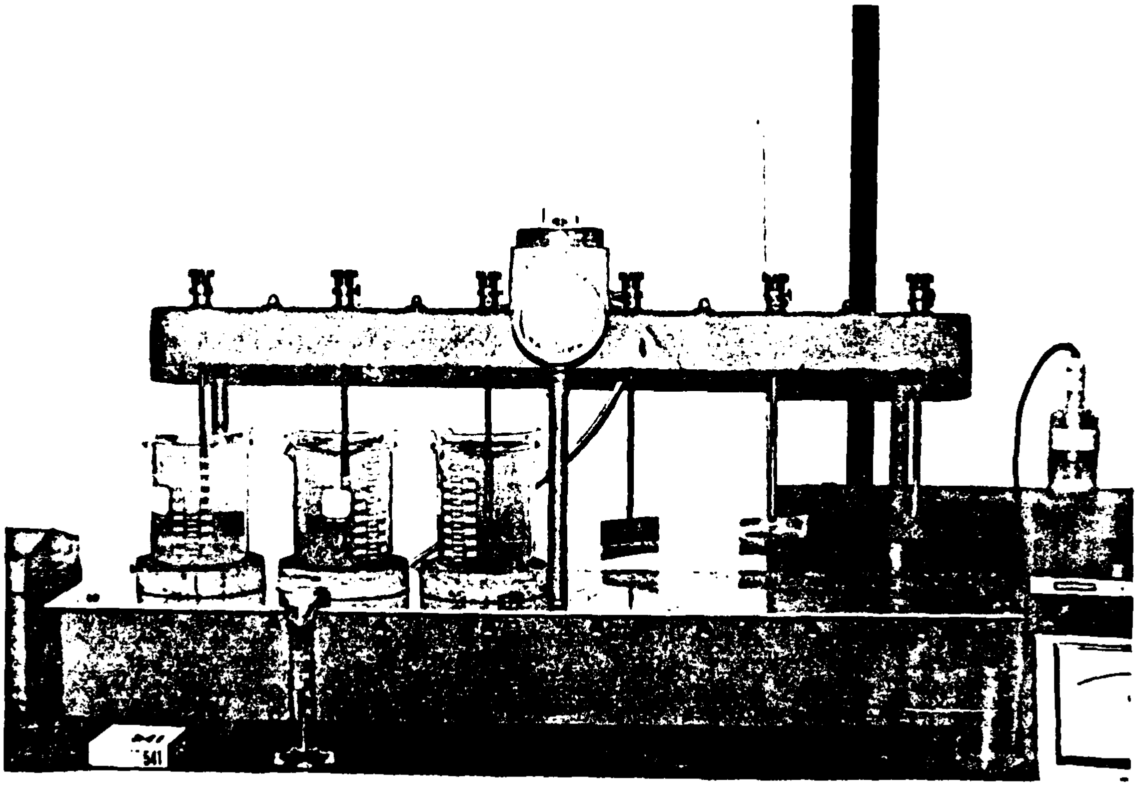

Figure 27. Beaker test apparatus (6 paddle stirrer in background, paper filter apparatus in front of it).

Sedimentation Versus Filtration

Comparison of turbidity values after immediate filtration of the flocculated suspension (Alternative a) and after filtration following 30 minutes of settling (Alternative c) indicated the two values to be quite similar. Therefore, Alternative c was eliminated because it unnecessarily added 30 minutes to the test kit procedure.

Visual observation of the suspension during flocculation indicated that the polymer was effective in floc formation. When no polymer was used, little or no floc was formed. When polymer was added and the suspension was allowed to settle for 30 minutes, a definite clarification zone was produced. However, substantial amounts of solids remained in the supernatant after thirty minutes. From a visual standpoint, the solids in the supernatant did not consist only of very fine suspended particles; large, lightweight particles and some floating particles also remained suspended. Thus, the supernatant was not representative of filter effluent such as the pilot filter might produce. For this reason and also because sedimentation was affected by small agitations and thermal changes, Alternative b was not considered to be worthy of further exploration as a test kit procedure. Further test kit evaluations involved only Alternative a.

POLYMER DOSAGE PREDICTIONS

Concurrently with the pilot filter tests depicted in Figures 16 to 17, tests were run with the beaker test apparatus.

Clay (90 to 110 FTU Tests)

Figure 28 shows that, in many respects, the dosage pattern defined by the beaker test kit was similar to that produced by the interface monitoring test kit. Turbidity decreased at a rapid rate as polymer dose was increased until a dosage of about 0.5 mg/l was reached, at which time the curve began to level off. This was the dosage at which the maximum run length for the pilot filter was found to occur (Figure 16).

Silt (26 to 35 FTU Tests)

Figure 29 shows that the beaker test kit produced a pattern for silt very similar to the one it produced for the clay, not a U-shaped curve with a minimum around 0.15 mg/l such as the pilot filter produced. The beaker test kit curve shows that a minimum may be occurring in the range of 2 to 8 mg/l.

PREDICTION OF EFFLUENT TURBIDITY

In the case of clay, once optimum polymer dosage had been reached, the beaker test kit closely approximated the effluent turbidity of the pilot filter at higher doses. In the case of the silt, however, the two patterns did not directly compare, although the values were still relatively close.

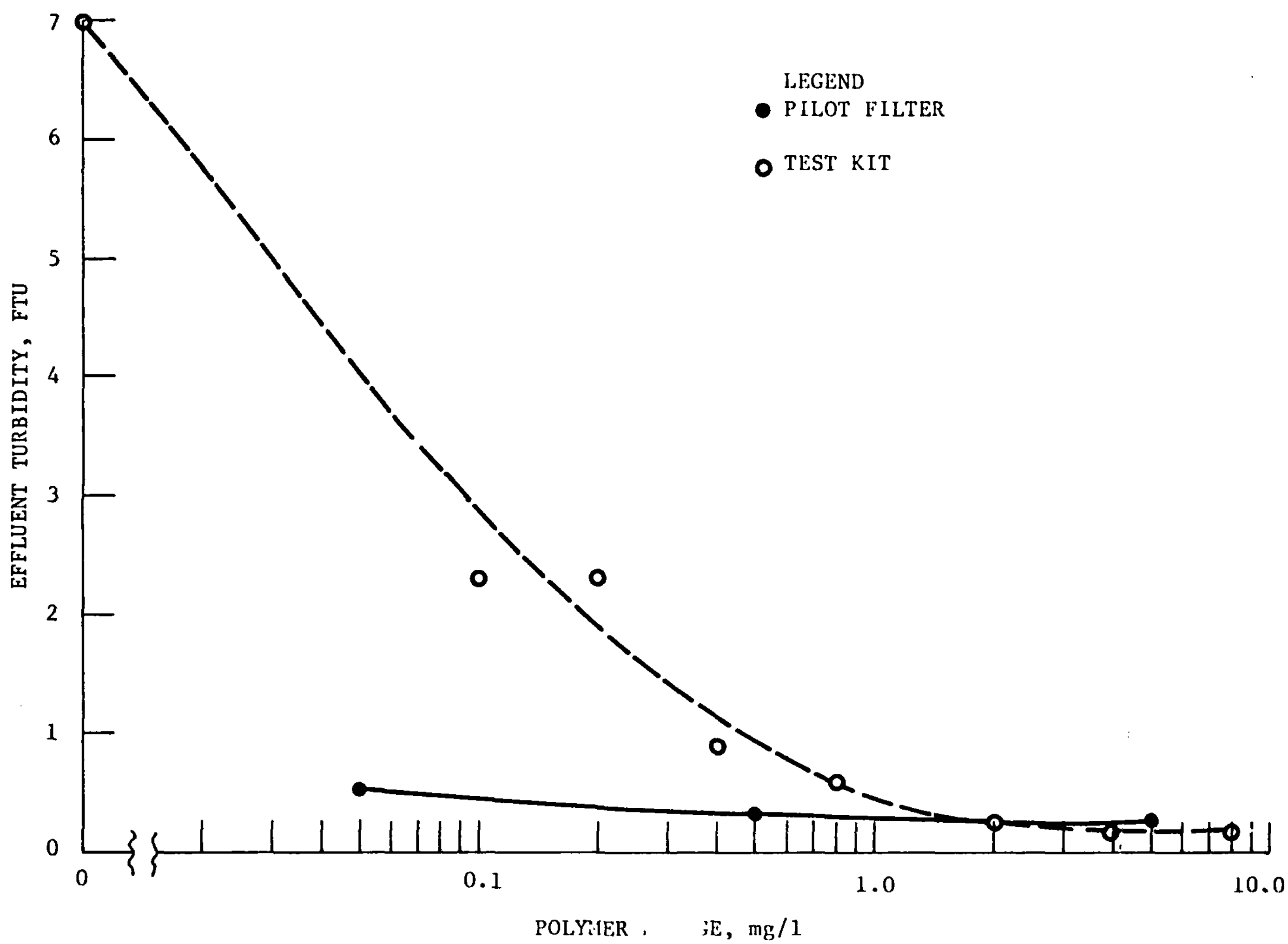

Figure 28. Compar'son of e luent turbidity between
pilot filter and beaker test kit.
(Material: clay; influent turbidity: 90-110 FTU)

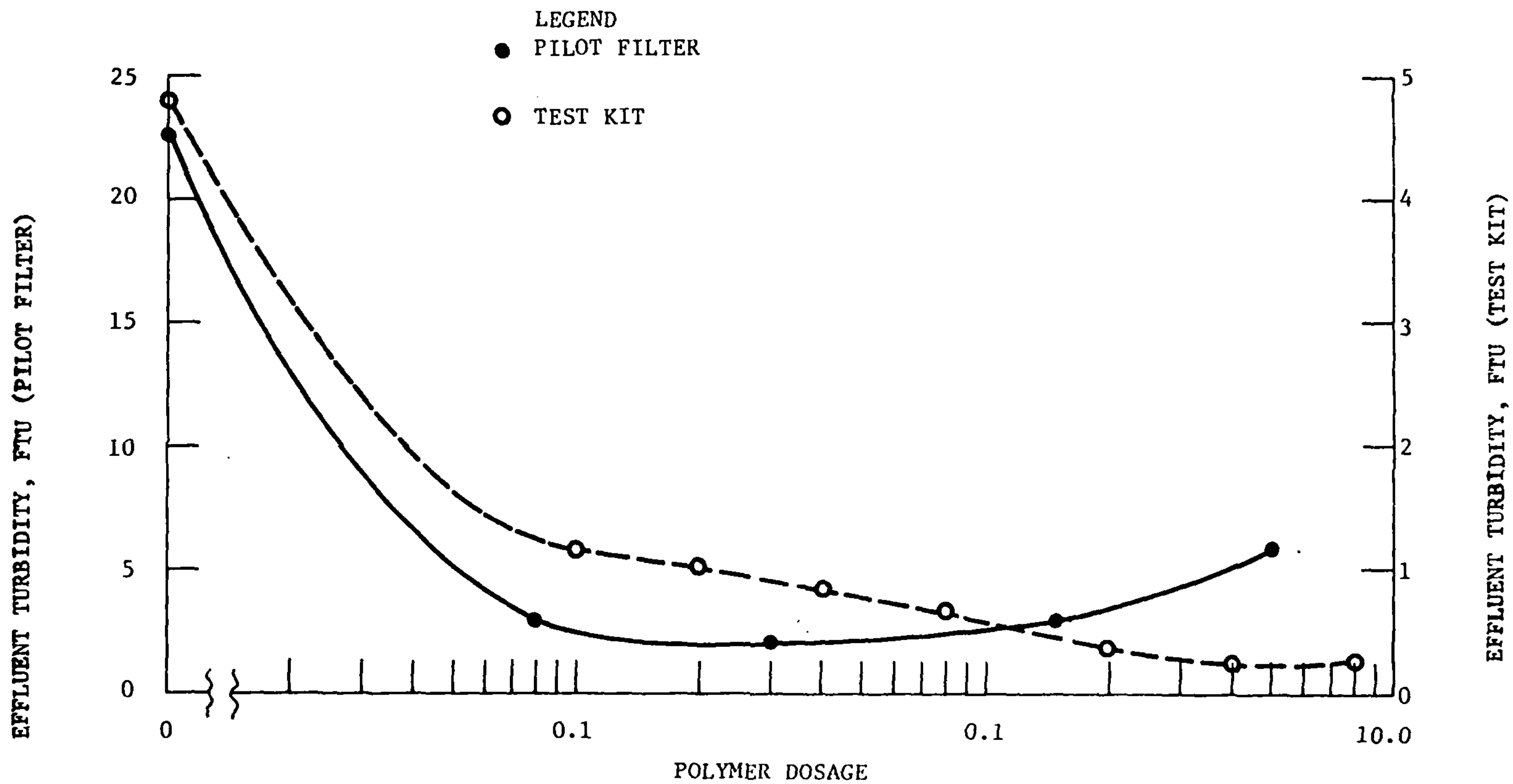

Figure 29. Comparison of effluent turbidity between pilot filter and beaker test kit. (Material: silt, influent turbidity: 26-35 FTU).

Summary of Beaker Test Kit Experiments

1. The beaker test kit was not a direct predictor of optimum dosage in the case of silt. It was a better indicator in the case of clay.

2. The effluent turbidity measured in the test kit was close to that measured in the pilot filter but the data patterns were not always similar.

3. The beaker test kit could give no indication of either run length or failure mode.

SECTION 7

DESIGN OF EFFLUENT MONITORING TEST KIT

In this section a proposed test kit for predicting optimum polymer dosage and effluent turbidity for the full scale filter will be described. The discussion will center on the test kit process, construction details, and the operating sequence.

PROCESS DESCRIPTION

A process schematic of the test kit is presented in Figure 30. Influent is pumped on a steady state, controlled basis through columns containing media. The first tests consist of adding different polymer doses to three sidestreams of the influent and filtering each of the sidestreams through separate columns containing only coal (three right hand columns on drawing). Measurement and comparison of the effluent turbidities from these columns allows the prediction of the optimum polymer dose for the full scale filter. Once the optimum polymer dose has been defined by the coal columns, these are shut off while the fourth column (far left on drawing) containing coal, silica, and garnet media, is operated to predict effluent turbidity for the full scale filter. Both sets of tests are completed within an hour, after which all four columns are backwashed to prepare them for subsequent use. The same pump which provides forward flow also backwashes the columns.

Polymer solutions are prepared for the test by mixing different concentrations of polymer in three separate polymer containers. A polymer feed drive draws the solutions into calibrated syringes and then feeds them at a constant rate just upstream of the columns. A static mixer (non-powered) thoroughly mixes the polymer with the influent prior to entering the column.

Other necessary components shown on Drawing 1 include:

1. Control valves and flowmeters for flow setting.
2. Barometric legs for keeping the media submerged.
3. Effluent catch beakers.

Other necessary components not shown on the process schematic include a garden tractor battery to power the unit, and an influent strainer to protect the pump from clogging with debris.

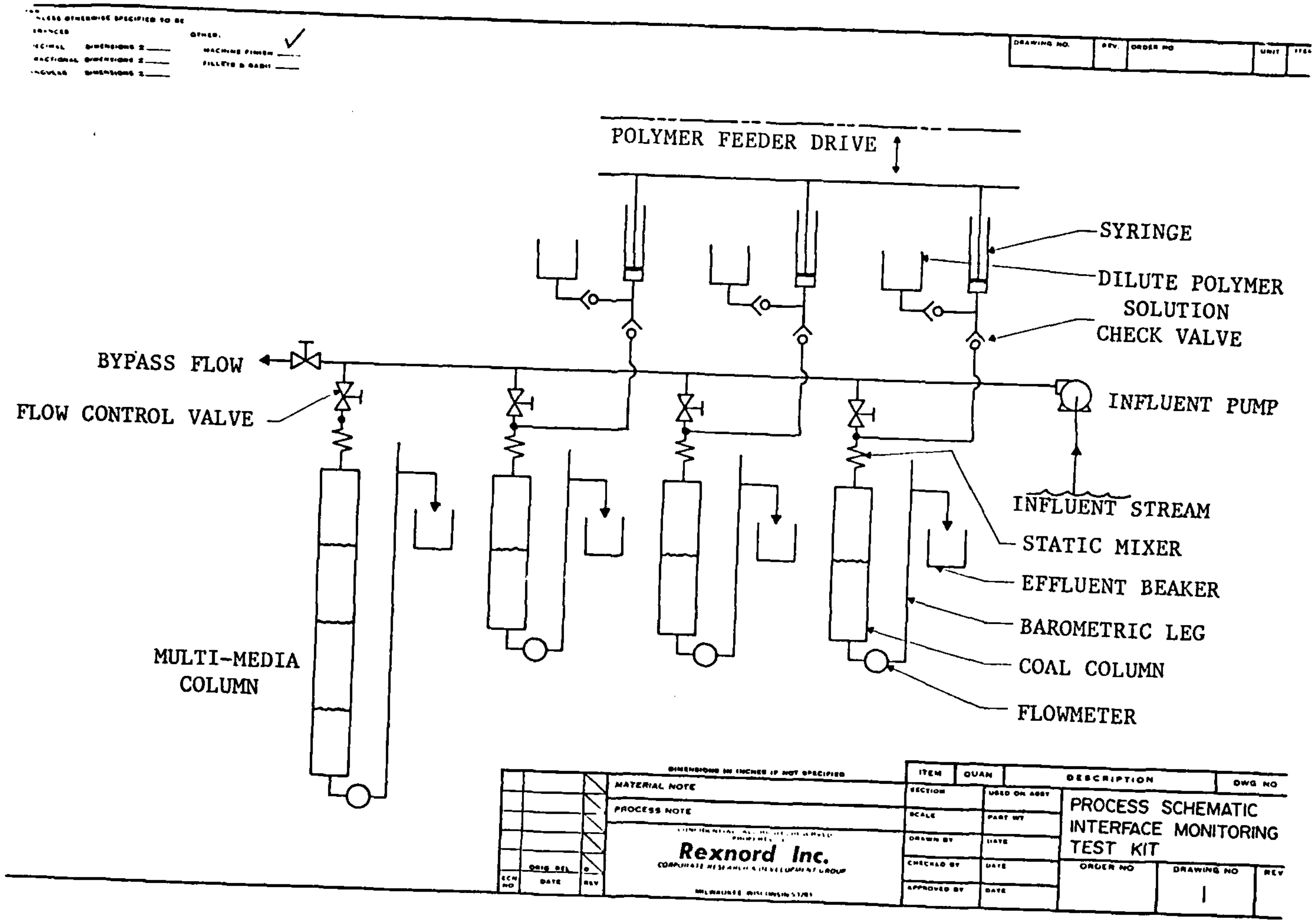

Figure 30. Process schematic of effluent monitoring test kit.

CONSTRUCTION DETAILS

All of the components shown on Drawing 1 are commercially available, off-the-shelf items and so assembly of the test kit will require little specialized engineering. Self-priming, low flow pumps are available (Example: Jabsco Flexible Impeller Pump, Model No. 12460-0011), as well as triple channel syringe pumps. However, it will probably be desirable to custom build a simple syringe pump using a DC gearmotor. The commercially available unit is much more complex and versatile than it need be for this application and it is not battery powered.

The power requirement for the sampler is under 70 watts and the test kit can operate five hours on a garden tractor battery before requiring battery recharge. The shipping weight will be approximately 75 lb (27 kg); one third of this weight will be the battery and another third will be the protective casing and fixtures for shipment and setup. The shipping size will be approximately 12 in. x 18 in. x 30 in. (30 cm x 47 cm x 75 cm).

OPERATIONAL SEQUENCE

The following is a generalized description of the steps involved in setup, measurements, and backwash.

Test Kit Setup

1. Select a suitable site for the test kit within a short distance from the influent stream.

2. Run a short length of garden hosing from the suction side of the pump in the sampler to the influent stream and another from the bypass valve back to the stream.

3. Push the stake on the inlet strainer into the stream bottom so that the strainer is supported above stream bottom materials.

4. Set up the column stand and attach the four prefilled columns. The polymer feed will be unitized and not require preassembly.

5. Connect the tubing to the columns by inserting the quick disconnect fittings.

6. Fill the three polymer solution beakers with clean water from the bottle in the test kit.

7. Using a pipette, add prescribed amounts of polymer to each polymer solution beaker.

8. Insert the polymer feed lines into the feed points for the three coal columns.

Test Kit Operation

1. Turn on the influent pump and wait until it primes and fills the bypass line with fluid.

2. Open the flow control valves and set each column flow at the red line on the flowmeter (12 gal./hour).

3. Take effluent turbidity readings from each column after thirty minutes.

4. Plot the readings on the special graph paper provided, connect the points with a curve and find the point at which the decreasing effluent turbidity appears to level off at a low value. That is the point of optimum polymer dosage.

5. (Optional). Shut off the pump. Close the valves for the three coal columns. Open the valve for the multi-media column, and prepare the optimum polymer dosage solution in one of the three syringe feed beakers. Turn the pump back on and filter the influent through the multi-media filter for thirty minutes at 12 gal./hour. An effluent turbidity sample taken after 30 minutes will closely approximate the effluent turbidity of the full-scale filter at optimum polymer dose.

Backwash

1. Turn off the pump.

2. Interchange the bottom and top tubes leading into each column using the quick disconnect fittings. (The flowmeters will not be used).

3. Remove the strainer from the stream, and place it in a 50 gal. container of filtered effluent water. (It may be desirable to postpone backwashing until the full-scale filter is in operation and the backfill storage tank begins to be filled).

4. Turn on the pump and open the flow control valves until the media in each column expand to predetermined levels for specified periods (same sequence as full-scale filter).

SECTION 8

CONCLUSIONS

1. The project objective was to develop a test kit which could predict "optimum" polymer dosage requirements for the full-scale Army filter. An "ideal" test kit would additionally be able to predict effluent turbidity, run length, and failure mode.

2. Attempts to find a simple test kit method which would require only the pouring of polymer-dosed influent through test kit media were unsuccessful. The transient nature of these test kits severely limited their ability to simulate full-scale, steady state multi-media filtration.

3. A small scale multi-media test kit, called an interface monitoring test kit, was successfully developed that approached the "ideal" test kit requirements. This test kit, which monitors effluent turbidity from the coal section, as well as through all the media, appears to be the most promising test kit method because:

    a. It uses the identical filtration mechanisms as the full-scale filter.

    b. It sensitively and accurately predicts optimum polymer dosage and closely approximates the effluent turbidity of the full scale filter.

    c. It is a renewable test kit, i.e., backwashing allows it to be repeatedly reused requiring only small quantities of polymer for each test.

    d. It can be constructed and repaired, if necessary, from off-the-shelf components.

4. A bench scale chemical flocculation test procedure was explored but was not found to correlate to the full-scale filter closely enough to be a useful tool for predicting optimum polymer dosage.

5. No test kit was found that could directly predict either run length or failure mode. However, it is thought that this important operational information can be established indirectly (see Recommendations, Item 2).

SECTION 9

RECOMMENDATIONS

1. A prototype interface monitoring test kit should be constructed and run side-by-side with the pilot filter on a variety of natural rivers and streams to validate the findings of the preliminary testing program which was done on clay and silt influents.

2. Characteristics of naturally occurring turbidity should be studied in conjunction with the validation tests to determine the relationships between these characteristics and the four predictive parameters, i.e., optimum polymer dose, effluent turbidity, run length and failure mode. These correlations could result in a technique for predicting run length and failure mode from the test kit measurements.

END

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